Time-based visual selection with emotional faces

by

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This thesis is dedicated to my grandparents.

The much loved, and deeply missed,

Audrey, Birch and Paul.

And the gloriously long-lived and glamorous, Sylvia.

Thank you for teaching me, above all, to be true to myself.

And to seize every opportunity Life throws my way.

And also, to my darling niece, Sophie.

Who has taught me that it is very important to laugh, long and loud.

(For no discernible reason, *whatsoever*!)

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These parts of theses are notoriously difficult to write, either exhaustively or dispassionately.

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Abstract

The biological and behavioural importance of the face has led to the proposition of several mechanisms dedicated to highly efficient specialized processing (e.g., M.H. Johnston, 2005). This is reflected in the attentional properties attributed to facial stimuli, especially when they contain affective information (e.g., R. Palermo & G. Rhodes, 2007). This thesis examines those attentional properties via a modified version of the visual search paradigm (i.e. the *preview search* task; D.G. Watson & G.W. Humphreys, 1997), which proposes that observers can intentionally suppress items seen prior to a full search array, for effective search performance (i.e. the *preview benefit*; D.G.Watson & G.W. Humphreys, 1997, 1998).

The findings from this thesis show that it is possible to deprioritize previewed facial stimuli from search, although only a partial preview benefit was shown. Emotional valence of previewed faces had little impact on this effect, even when preview duration was extended from 1000-3000ms. However, when duration was reduced to 250-750 ms, negatively valenced faces were more difficult to suppress than positively valenced faces. In addition, when previewed faces changed expression concurrently with the onset of the full search array, the preview benefit was abolished, irrespective of the direction of the expression change (i.e. neutral to positive, or neutral to negative). A search advantage for negative face targets was demonstrated throughout all of the investigations in this thesis. These findings are consistent with previous work establishing preferential detection of, and selectively impaired disengagement from, negative faces (e.g., J.D. Eastwood, D. Smilek, & P.M. Merikle, 2001; E.Fox, R. Russo, R.J.Bowles, & K. Dutton, 2001). However, they also suggest the sensitivity of the visual marking mechanism to ecological considerations (such as the nature of the stimulus), and the overall relevance of emotional face stimuli to the visual system.

Table of Contents

List of Figures

List of Tables

Chapter 1

Faces: What, how and why?

"The human face – in repose and in movement, at the moment of death as in life, in silence and in speech, when seen or sensed from within, in actuality or as represented in art or recorded by the camera – is a commanding, complicated, and at times confusing source of information."

Ekman, Friesen and Ellsworth (1972, p1)

1 Faces: What, how and why?

1.1 Overview

This chapter will be a particularly eclectic one. In its role as the first introductory chapter of this thesis, it will address the aspects of face processing most relevant to the empirical work presented later; in other words, the “*what?*” and “*how?*” of the face processing and facial expression literatures. Specifically, it will look briefly at how face processing is understood, via both cognitive mechanisms and underlying neural architecture. In addition, it will address how facial expression is processed; examining evidence from a more social psychological perspective. Lastly, in the course of those reviews, it will briefly discuss those facets of this processing that set faces apart from other objects in our visual environment- in essence, the “*why?*”.

However, before those themes are explored, this chapter will present the main aims and objectives of this thesis, together with the overarching research questions that motivate its empirical investigations. This might appear self-indulgent to the reader, perhaps even superfluous. However, at the beginning of what is often acknowledged as the *Herculean* labour of any doctoral student, it is useful to focus on why this particular task has been chosen. This is where this thesis begins.

1.2 Aims and objectives of this thesis

Faces are hugely important to us as social beings. Through their visual salience (e.g., Rousselet, Macé, & Fabre-Thorpe, 2003) and ecological relevance, they appear to dominate our cognitive processing (e.g., Pegna, Khateb, Michel, & Landis, 2004; Lavie, Ro & Russell, 2003; Mineka & Öhman, 2002) and influence multiple facets of our behaviour (e.g., Ro, Russell, & Lavie, 2001; Wilson & MacLeod, 2003; Wong & Root, 2003; Murphy & Zajonc, 1993). In fact, phenomenologically speaking, it is possible to suggest that the faces of those around us impact upon almost every area of our lives, and from the first moment we are born (e.g., Valenza, Simion, Macchi Cassia, & Umiltà, 1996; Johnson, Dziurawiec, Ellis, & Morton, 1991; see Pascalis & Kelly, 2009 for a review). It is also possible to say that this impact is heightened by the addition of facial affect (amongst other factors, such as familiarity or specific identity). Ordinarily, how many humans fail to experience some response to facial displays of joy or sorrow? Or to a familiar face, searched for in an unfamiliar context?

However clearly, this is not a scientific view to propose. How it *feels* to scrutinize another's facial expression, or to scan a crowd for a familiar face, does not contribute to understanding human behaviour more fully. Nor does it allow us to draw valid conclusions from what observations we might make in the course of our experience. This is the underlying motivation for this thesis; to understand how emotional faces affect behaviour in the domain of visual attention. Despite the face's ubiquity in everyday experience and inherent emotional content, if a representation of the human face is placed into a robust experimental paradigm, it *is* possible to investigate the effects of an emotionally valenced face in a scientifically rigorous manner.

This thesis aims to fulfill precisely the objective stated above. It will evaluate the impact of emotionally valenced faces within an experimental context (i.e. visual search) that has been extensively examined previously, and thus, is both well-controlled and easy to manipulate, scientifically speaking. However, it will also introduce an element of innovation to that experimental context. Whereas most previous work (i.e. visual search with emotional faces) has focused on the *attention-attracting* properties of an emotional face (i.e. attention capture attributable to a specific facial expression; see Hansen & Hansen, 1988; Hampton, Purcell, Bersine, Hansen & Hansen, 1989; Purcell, Stewart, & Skov, 1996; Öhman, Lundqvist, & Esteves, 2001; Eastwood, Smilek, & Merikle, 2001; Fox et al., 2000; Hortsmann & Bauland, 2006; and see Frischen, Eastwood, & Smilek, 2008; Horstmann, 2007 for reviews) this thesis will explore the reverse attentional function. By using a paradigm (i.e. *preview search*, see Watson & Humphreys, 1997) that is suggested to rely on the ability to *ignore* stimuli presented to an observer (rather than purposefully orient attention to them), a different facet of the face's attentional properties is examined.

In summary, this thesis will determine whether it is possible to ignore a representation of a human face; and in particular, whether different emotional content results in differential processing in this context. This is important to issues of both social fluency and efficient processing, since arguably, any degree of cognitive flexibility should allow some mastery over even behaviourally-relevant stimuli. However, this would present a striking contrast to the literature suggesting that affective faces (specifically, those that show an expression that is threatening to the observer) are processed with high efficiency, for example, by a dedicated fear-oriented module (i.e. LeDoux, 1996; 1998; Öhman & Mineka, 2001). In exploring the parameters of any differential processing attributable to facial affect, the following thesis will examine not only a stimulus of direct social and adaptive relevance to human function, but also its operation within cognitive and behavioural constraints.

1.3 Processing the Face

At the outset of this section, it is important to underline the magnitude of the face processing literature. In line with its behavioural importance to human functioning, understanding how faces impact on our thoughts and actions has been a focus of enquiry since ancient philosophers debated the nature of the universe (e.g., Aristotle, n/d 1913). Indeed, biblical references[1] suggest that human understanding of the fundamental links between facial expression, emotion and behaviour have had a profound influence on human experience and beliefs for centuries. This focus is still reflected today, with a proliferation of sophisticated electrophysiological investigations into specific processing centres and neural correlates of face processing (e.g., Santesso et al., 2008; Evans et al., 2008; Eimer & Holmes, 2007; Wang, McCarthy, Song, & LaBar, 2005; Winston et al., 2004; Grill-Spector, Knouf, & Kanwisher, 2004; Kawasaki, et al., 2001). As a result (and perhaps, unsurprisingly), this makes the face processing literature a rich, but sprawling, source of information.

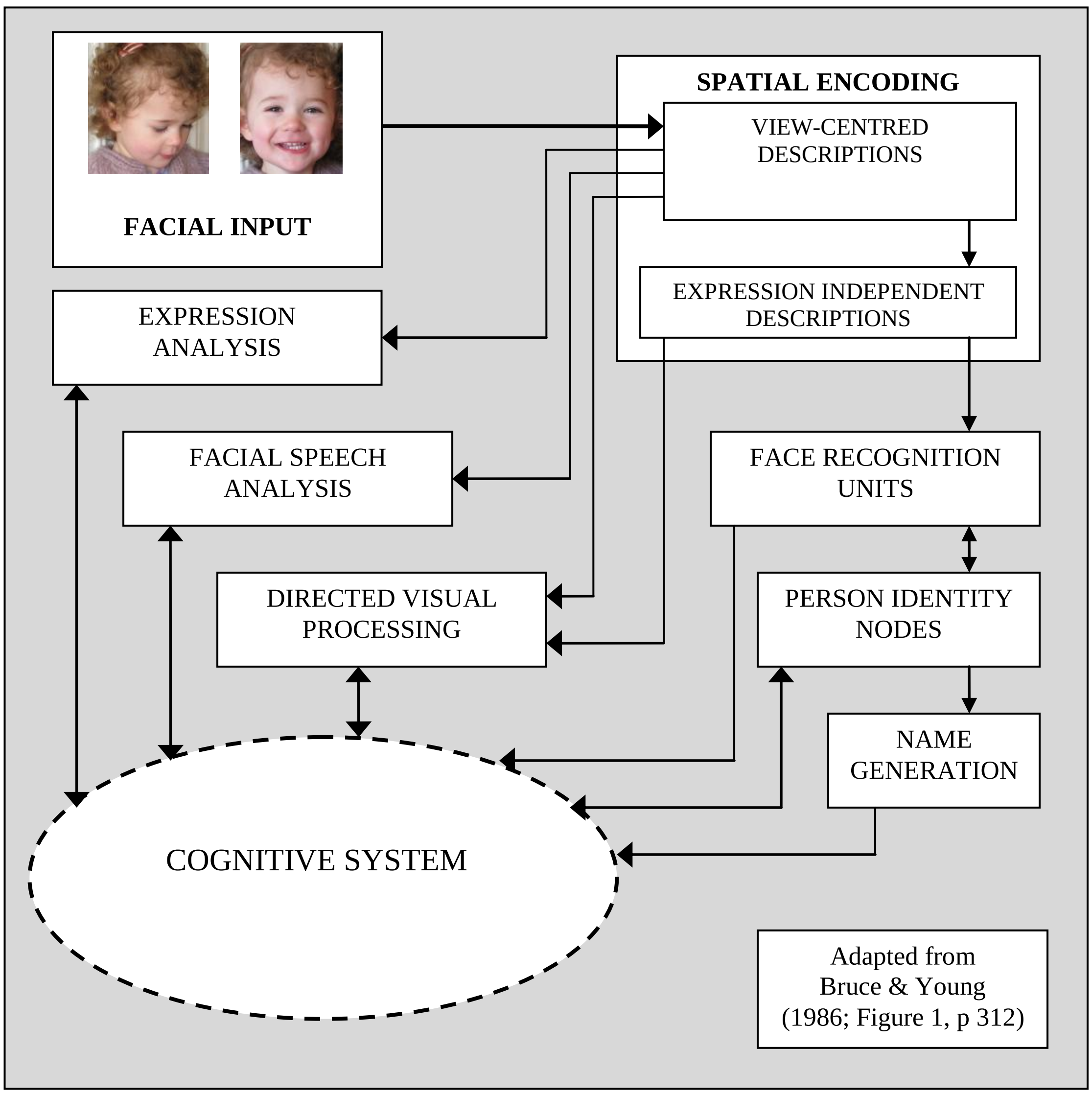
Necessarily then, this section aims to be selective and highly focused in its outlook. Inevitably, this means that considerable amounts of information may have to be overlooked; however, there are also portions of the literature that are not entirely relevant to this thesis (e.g., discussion of mechanisms implicated in face recognition). Thus, these will only be addressed insofar as they impact upon general processing mechanisms and specific affective face phenomena.

[1] For example, a passage from Ezekiel (39.18), which quotes God as saying "…My fury shall come up in my face."

1.3.1 *Face processing models and neural substrates*

Bruce and Young (1986) were amongst the first to provide a comprehensive functional model of face processing (see Figure 1.1 below; see also Calder & Young, 2005, for an overview). Whilst the focus here was arguably face recognition–centred, its operation spoke directly to the underlying functions attributed to general face processing.

Figure 1. 1 Bruce and Young's (1986) cognitive model of face processing



Moreover importantly, this model acknowledged the need to distinguish between functions of face recognition and facial expression identification.

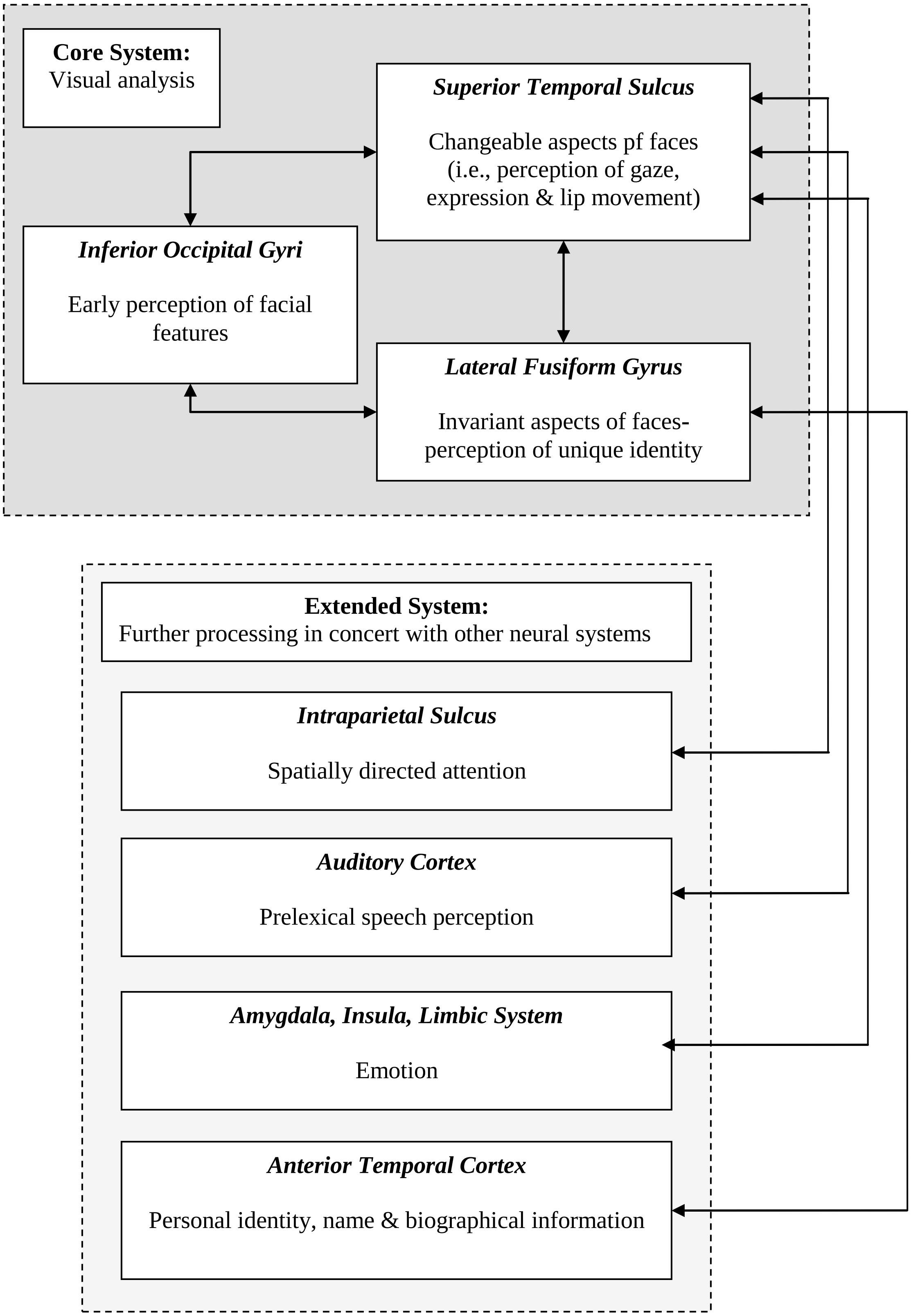
Bruce and Young (1986) proposed a modular system comprising an initial structural encoding mechanism of an observed face, using viewer-centred "descriptions". These then fed into separate modules processing i) emotional expression, ii) facial movement aspects of speech, iii) visual coding of attributes, discernible by appearance (i.e. sex, race, or age), and finally, iv) recognition of familiar faces. This last module fed into a process, by which facial familiarity was determined, semantic and biographical information associated with an individual retrieved, and labelling by name made.

Whilst this straightforward model reflects the diversity of functions indicated by a distributed face processing system, it remains difficult to map onto the underlying neuroanatomy. In fact, Breen, Caine and Coltheart (2000) suggested that the "conflation of these two levels of description…has seemed to imply a neuranatomical underderpinning to the cognitive modelling of two separable routes to face [processing]. This is problematic…" (p 55). That said, neuropsychological evidence has led to a general acceptance of a dual-route face processing system (e.g., Bauer, 1984; 1986; Tranel & Damasio, 1985; Ellis & Young, 1990). For example, a patient with prosopagnosia demonstrated a stronger skin conductance response (SCR) when shown familiar faces than unfamiliar ones, despite no overt recognition of the facial stimuli (Bauer, 1984; 1986). Bauer asserted that this autonomic response constituted implicit recognition of the familiar face.

In contrast, Ellis and Young (1990) explicitly attributed the SCR to activation of affective information associated with a particular face, when applying a dual- route model to patients with Capgras Syndrome (i.e. Capgras & Reboul-Lachaux, 1923; Todd, 1957). This syndrome might be seen as a counterpoint to prosopagnosia, in that patients recognize the familiar face presented to them, but have the delusional belief that this person has been replaced with an impostor. Ellis and Young (1990) proposed that this symptomology was the result of damage to a secondary face processing route for affective information, meaning that patients could process identity information, but not the corresponding emotional information (see also Ellis et al., 1997; Hirstein & Ramachandran, 1997; for converging evidence).

Since Bruce and Young's (1986) *cognitive* conceptualization of a distributed face processing system, several further models have been explored, attempting to account for both cognitive function and neural architecture (e.g., Ellis & Young, 1990; Breen, Caine & Coltheart, 2000). Haxby, Hoffman and Gobbini (2000, 2002) have presented a consistently influential distrubuted model, which similarly to Bruce and Young (1986), maintains functionally and neurologically distinct streams for processing facial identity and facial expression. Their model presents three cortical areas for the *core* visual processing of faces; the inferior occipital gyri (IOG), superior temporal sulcus (STS) and lateral fusiform gyrus (i.e. the fusiform face area or FFA; see Kanwisher, McDermott, & Chun, 1997). Respectively, these are thought to be responsible for early perception of facial features (IOG), changeable aspects of faces (i.e. facial expression, gaze or lip movement; STS) and fixed aspects of faces (i.e. unique identity, FFA).

Figure 1.1 A model of the distributed human neural system for face perception



Adapted from Haxby, Hoffman, & Gobbini (2000; Figure 5, p230*)*

In addition, Haxby et al., (2000) also proposed a number of interconnected cortical and subcortical regions that extend the function of the face processing system to processing attentional, semantic and affective information associated with facial stimuli. The latter of these functions, undertaken by the amygdala, insula and limbic system in general, are most relevant to the processing required for evaluation of emotionally valenced faces, in concert with the operation of the STS. Despite a substantial amount of research continuing to examine specific mechanisms within this distributed system and proposing alternative ways to explore its operation (e.g., Tsao & Livingstone, 2008; Susskind et al., 2007; Calder & Young, 2005), this model retains strong explicatory power within the cognitive and neuropsychological literatures. Individual face processing mechanisms and brain areas will be discussed below, insofar as they are implicated in processing facial affect.

1.3.2 *Subcortical face processing*

One aspect of the distributed face processing system that Haxby et al.,(2000) alluded to in their model, is its interconnection with subcortical structures mediating affective and behaviourally relevant processing (i.e. the amygdala, insula and limbic system). Moving away from a "cortico-centric" perspective (Johnson, 2005), this introduces the concept of a mode of subcortical face processing; one not simply subordinate to cortical processing, but actually modulating its function (Johnson; 2005; see also Iidaka et al., 2001; George, Driver, & Dolan, 2001). Johnson suggests that this acts as a rapid face detection mechanism, operating on low spatial frequency (LSF) input, involving the superior colliculus, pulvinar and amygdala. Despite its potential importance to the detection of behaviourally relevant face stimuli (i.e. emotionally valenced faces), its contribution to preferential face processing remains contentious (see for example, Krolak-Salmon et al., 2004; Cowey, 2004).

Evidence for this pathway has been presented from a number of perspectives. Firstly, neuro-psychological data is highly suggestive of residual face processing capabilities (particularly the presence of faces and some facial expression), even where normal visual cortex function has been disrupted (e.g., in patients with blindsight, see Morris, de Gelder, Weiskrantz & Dolan, 2001). In addition, patients exhibiting hemispatial neglect have shown the ability to detect a stimulus resembling a face, in the field that normally demonstrates extinction (e.g., Vuilleumier & Sagiv, 2001; Vuilleumier, 2000). In addition, the rapidity of neural response, evidenced by Event-Related Potentials (ERPs) and Magnetocephalography (MEG) studies, can also be seen to occur prior to face-specific neural correlates associated with cortical activity (e.g., the N170 and M170) at latencies of less than 100ms (see Eimer & Holmes, 2002, Streit et al., 2003, Braeutigam, Bailey, & Swithenby, 2001; Pourtois et al., 2005). This suggests a face-selective response, before activation of the primary visual cortex, and in conjunction with evidence of selective activation to threat/ fear facial components in the amygdala, after approximately 200 ms (e.g., Braeutigam et al., 2001; Bailey, Braeutigam, Jousmaki, & Swithenby, 2005).

Further evidence for the operation of a face-selective subcortical mechanism can be adduced from processing of the LSF information that can be derived from faces. This information, consistent with broad facial configuration rather than facial detail, is carried by magnocellular pathways to the superior colliculus and pulvinar- and is considered most suited to a “quick and dirty” visual route, designed to detect threatening stimuli (i.e. Johnson, 2005; see Livingstone & Hubel, 1988; Merigan & Maunsell, 1993; Schiller, Malpelli, & Schein, 1979; for converging neurophysiological evidence). Moreover, the preference of neonates for facial stimuli over equivalent stimuli (i.e. those matched for contrast, motion etc.; see Johnson et al., 1991), has been attributed to infants' preferential processing of LSF input, prior to maturation of cortical visual areas (e.g., Morton & Johnson, 1991; de Schonen & Mathivet, 1989). Moreover, although the subcortical structures involved in facial processing are, comparatively, more developed at birth (i.e. than cortical visual processing centres), infants do not appear to demonstrate the same selective responses to fear or threat faces as adults do (see Atkinson, 2000; Johnson, 1990; for reviews).

Conversely, high spatial frequency information (HSF) about faces has been shown, in functional Magnetic Resonance Imagery (fMRI) studies, to elicit selective activation in the FFA, and to maintain these representations over time (e.g., Vuilleumier, Armony, Driver, & Dolan, 2003). Thus, it appears that HSF information is likely to be important for facial identity coding, whereas the subcortical route (remaining unresponsive to HSF information), is best suited to rapid detection of faces in the environment. Moreover, the operation of a LSF-responsive subcortical route would be particularly important in the adaptive detection of potential threat, in the form of negatively valenced facial expressions, as this can also be conveyed by LSF information (e.g., Winston, Vuilleumier, & Dolan, 2003; Schyns & Oliva, 1999).

1.3.3 *Preferential processing of facial affect*

Although faces can be described as inherently emotional (e.g., on the basis of their familiarity, attractiveness, race, or direction of gaze; e.g., Palermo & Rhodes, 2007)[2], independently from their emotional content, arguably it is this aspect that is most likely to have privileged access to visual processing. Calvo and Esteves (2005) have presented behavioural evidence that unambiguously emotional faces require lower thresholds for detection, and neurophysiological studies have indicated that affective information is encoded and discriminated from faces extremely rapidly; from as soon as 80 ms post stimulus onset (see Palermo & Rhodes; 2007, p78, for an extensive review of the time course of emotional face processing). Moreover, these rapid detection, discrimination and explicit recognition functions have been demonstrated in a number of cortical (e.g., occipital, temporal and frontal; see Pizzagalli, Regard, & Lehmann, 1999; Poutois, Grandjean, Sander, & Vuilleumier, 2004; Eimer & Holmes, 2002; Holmes, Vuilleumier, & Eimer, 2003; Kawasaki et al., 2001; Batty & Taylor, 2003; Liu, Iaonnides, & Streit, 1999) and subcortical regions (i.e. amygdala and insula; see Streit et al., 2003; Liu et al., 1999; Cowey, 2004; Krolak-Salmon et al., 2004).

Automaticity of processing is one benchmark by which preferential processing might be evaluated. In any event, fulfilment of one or more of the criteria taken to indicate automatic processing would be strong evidence of a special status for mechanisms associated with facial expression. The neurophysiological data referred to above (see Palermo & Rhodes, 2007) seems prima facie, to satisfy the *rapidity* criterion (see also; Batty & Taylor, 2003; Öhman, 1997).

Evidence can also be drawn to support the *non-conscious processing* of facial affect. Where emotional face primes are presented very briefly (for ~15ms) and immediately backward masked, observers demonstrate a robust effect on their

[2] see also Compton, 2003; for further discussion of the impact of emotionally significant stimuli on attentional processing.

subsequent affective ratings of neutral symbolic stimuli (i.e. following a happy face prime, symbols are rated as more appealing, than after an angry face prime; e.g., Murphy & Zajonc, 1993; Rotteveel, de Groot, Geutskens, & Phaf, 2001; Wong & Root, 2003). Moreover, briefly presented affective faces (~30ms) can elicit facial mimicry (seen via electromyography (EMG); e.g., Dimberg, Thunberg, & Elmehed, 2000) or conditioned autonomic responses (e.g., Esteves, Dimberg, & Öhman, 1994) associated with specific emotional expressions, although observers have no conscious awareness of the corresponding facial stimuli.

Leaving aside neuropsychological evidence at this point, neuroimaging studies with healthy participants also indicate selective activation of subcortical structures such as the amygdala, in response to fearful faces or fear conditioned angry faces (e.g., Whalen et al.,1998; Morris, Öhman, & Dolan, 1998; Morris et al., 1999; see Zald, 2003; for a review). However, this effect appears reliable only when observers have no awareness of the threatening faces they are processing (but cf. Philips et al., 2004; Pessoa, Japee, Sturman, & Ungerleider, 2006). This may imply that subcortical facial processing is only directly invoked in highly specific circumstances; for example, when the content of facial stimuli is ambiguous or subject to very brief exposure. That said, selective amygdalar activation in response to happy faces rather than neutral faces (Williams et al., 2004) is suggestive of a wider function. Perhaps then, the subcortical face processing route is adapted to differentiate between affective and non-affective faces, but not to categorize them thereafter.

A third criterion for automaticity, or in this context, evidence for privileged status, is *mandatory* processing. Facial stimuli, in general, appear to be difficult to ignore (e.g., Suzuki & Cavanaugh, 1995), even when local task-based processing demands should outweigh global awareness of a facial configuration (see also Lavie, Ro, & Russell, 1995; for an example in the *perceptual load* literature). This effect seems accentuated by the addition of facial affect (e.g.; Fox, 2002; Vuilleumier & Schwartz, 2001; but cf. Mack & Rock, 1998), however in contrast, neurophysiological studies suggest that this advantage may be only partial. For example, activation in the FFA (e.g., McCarthy, 2000; O'Craven, Downing, & Kanwisher, 1999; Wojciulik et al., 1998) and the magnitude of some face-selective neural components (e.g., the N170/M170; Downing, Liu, & Kanwisher, 2001; Eimer, 2000; Holmes et al., 2003) is enhanced by the presence of focused attention, rather than its absence. However, the neurophyisological evidence is not unequivocal (see also, Carmel & Bentin, 2002; Cauquil, Edmonds, & Taylor, 2000).

Moreover, some studies examining amygdalar activation in response to emotional faces (e.g., Anderson et al., 2003; Vuilleumier et al., 2001; Williams, McGlone, Abbott, & Mattingley, 2005a), suggest that processing is mandatory and does not require attentional resources (see below). Vuilleumier et al., (2001) examined the response of the amygdala, when a pair of houses or fearful faces, presented peripherally, were matched (i.e. fearful faces were presented in both cases, but the focus of attention was manipulated). No differential activation was observed corresponding to whether participants actively attended the fearful faces or not; moreover, this effect has been replicated where stimuli are presented foveally (e.g., Anderson et al., 2003). However, subsequent research has suggested that these findings should be treated with caution; for example, Pessoa, McKenna, Guiterrez, & Ungerleider (2002) have asserted that activation is modulated by attentional load (but cf. Williams et al., 2005).

In addition, it is also possible that individual differences between participants may account for differential amygdalar activation. In a replication of Vuilleumier et al.'s (2001) study described above, Bishop, Duncan and Lawrence (2004) tested both high and low anxiety individuals. Although equivalent activation for attended and unattended fearful faces was demonstrated for high anxiety participants, enhanced activation was only shown in respect of attended fearful faces for participants with low levels of anxiety. This correlates broadly with evidence from behavioural studies (i.e. Fox, 2002; Fox, Russo, Bowles & Dutton, 2001; Mogg & Bradley, 1999; Georgiou et al., 2005; de Jong & Martens, 2007), where the attentional properties of emotional faces appear heightened in these circumstances.

A final criterion for determining automatic processing revolves around capacity limits and resource demands. The requirement of little cognitive resource, so that disruption from concurrent tasks is minimal, is held as characteristic of automatic processing (see Schneider & Chein, 2003). However it should be noted that, according to Palermo and Rhodes (2007), conflation of the *mandatory* and *capacity-free* processing criteria occurs frequently in the face processing literature, due to the dual-task paradigms often used. They assert that, theoretically, these two criteria can occur independently (i.e. face processing can be mandatory, without being capacity-free, or vice versa.).

Demands on processing resource have often been evaluated by examining visual search with emotional faces (i.e. Eastwood et al. 2001; Fox et al., 2000; Öhman et al., 2001; see Frischen et al., 2008; for a review). However, this paradigm is examined in considerable detail in the third chapter of this introduction on account of its relevance to empirical work in Chapter Four onwards. For this reason, discussion of resource demands relevant to emotional faces will be confined to the coding of facial affect.

As described above, Pessoa et al., (2002) found that neural response was eliminated in all face-selective brain regions, when faces were unattended. As a result, Pessoa et al., (2002) concluded that processing of facial affect was *not* mandatory *or* capacity-free. However, in most dual-tasks paradigms where attention is directed away from facial expression, FFA response is diminished, but not eliminated. Moreover, amygdalar activation remains equivalent- overall, suggesting that cortical processing may be reduced by a corresponding reduction in attentional resources, but that subcortical processing is unaffected (see Anderson et al., 2003; Vuilleumier et al., 2001; Wiliams et al., 2005).

Alternatively, it may be that processing demands are, in fact, reduced in the case of emotional stimuli (Anderson, 2005). In an earlier neuropsychological study using emotional words rather than faces, Anderson and Phelps (2001) found that healthy participants were more likely to accurately report the second target in an Attentional Blink (AB) task, when it was negatively valenced, rather than neutral. The authors suggested that this was consistent with amygdalar involvement in early perceptual coding of emotional-significant stimuli. In turn, this meant that, subsequently, these stimuli would be less reliant on the deployment of attentional resources to reach awareness.

In contrast, whilst demands upon processing resource do not seem to impact on subcortical activation generally, it may be that structures such as the amygdala *are* sensitive to processing load, in terms of function. For example, under circumstances of low processing load, selective activation is demonstrated in respect of fearful faces (even where attentional resource is allocated elsewhere). However, when load is high, this activation appears to arise from all negative face input (i.e. all potentially threatening facial expressions; see Anderson et al., 2003), but not from positive faces (i.e. Williams et al., 2005a). This suggests that *specificity* is lost when attention is depleted, and whilst LSF (i.e. subcortical) input can facilitate broad differentiation between negative and positive faces, it cannot differentiate between categories of negative expression (e.g., Palermo & Rhodes, 2007). This role may be fulfilled by more resource-dependent cortical processing.

Neuropsychological evidence may also elucidate the cognitive resources needed for coding individual features, and in turn, necessary for determining facial affect. Eye movement studies indicate that healthy participants fixate on all the facial features of emotional faces, but particularly on the eye and mouth regions (see Green & Phillips, 2004; for a review). Thus, attentional resources may be required to discriminate between specific facial indicators of negative emotions (such as the eyebrows or eyes for facial threat, or the nose for disgust) and the amygdala may be implicated in directing attention to those features (e.g., Palermo & Rhodes, 2007). However, in cases of atypical development (e.g., Spezio, Adolphs, Hurley, & Piven, 2007; for evidence appertaining to Autistic Spectrum Disorders) or functional disruption in neuropsychological patients (see Adolphs et al., 2005), patterns of abnormal amygdalar activation and unusual scanning of facial features appear to co-occur with marked deficits in recognition of facial affect (see Vuilleumier, 2005; for further discussion). This processing appears particularly impaired in respect of negative valenced faces (e.g., Adolphs, Tranel, & Damasio, 2001; Adolphs, Tranel, Damasio, & Damasio,1995; Adolphs et al., 1999; Anderson, Spencer, Fulbright, & Phelps, 2000).

In summary then, whilst distinctions between basic categories of facial affect (e.g., fear and happiness; Pourtois et al., 2004; Kawasaki et al., 2001) can be made rapidly, without conscious awareness (e.g., Whalen et al., 1998; see Zald, 2003; for a review), this appears to preclude more sophisticated differentiation between facial expressions. In addition, some affective facial stimuli appear to be mandatorily processed (e.g., fearful faces; Williams et al., 2005a). However, there seems to be some heterogeneity in findings, in accordance with task-dependent loading of cognitive resources or individual differences (see Palermo & Rhodes, 2007). Evidence suggests that much of this automatic (or at least, preferential) processing is mediated by a subcortical face processing route, although this also indicates a trade-off between an adaptive “threat detector” (see Öhman & Mineka, 2001; LeDoux, 1996,1998) and relatively impoverished information that requires additional resources to be fully processed. This may be facilitated by cortical processing pathways, such as those indicated in Haxby and colleagues’ (2000) model.

1.3.4 *Specialized cognitive mechanisms for face processing*

To this point, this introduction has focused, almost exclusively, on the neuroanatomy and cognition associated with processing of affective faces. However, there are also specialized cognitive mechanisms that are relevant to processing emotional faces, despite their usual association with facial recognition. These fall broadly under two interrelated umbrella terms: firstly, *holistic processing* (e.g., Farah, Wilson, Drain, & Tanaka, 1998), a perceptual mechanism by which faces are processed rapidly and efficiently as a *gestalt* whole, rather than by their constituent parts. Secondly, *expertise effects* (e.g., Diamond & Carey, 1986) where differential processing of facial stimuli is facilitated by frequent exposure and subsequent expertise with the particular stimulus type. It should be noted that some commentators assert that holistic face processing is simply a specialized form of more general expertise effects (e.g., Gauthier & Tarr, 1997; Diamond & Carey, 1986). Moreover, this would mean that holistic processing and/or expertise effects are generalizable to a far wider range of objects than might be supposed (i.e. any object with which the observer has a high degree of exposure or familiarity). This debate will be discussed in more detail below.

1.3.4.1 *Holistic processing of faces*

Maintaining a distinction between holistic processing and expertise effects underlines the assumption that faces are perceptually processed in a different manner to other objects. Given the potential behavioural significance of faces, whether their affect or identity is most important, this would not be particularly unexpected. Farah et al., (1998) compared the perceptual mechanisms underlying processing of faces, objects and words, from a recognition perspective. In this study, Farah and colleagues used a matching task, with briefly presented stimuli masked by whole and part stimulus masks (i.e. whole face and whole word masks, compared with facial feature and non-word masks), and a subsequent stimulus, of the same type as the first.

Following Johnston and McClelland's (1980) logic that words could be equally well masked by whole word and non-word masks (i.e. masks composed of letter sequences, rather than a recognizable word), Farah and colleagues (1988) reasoned that if faces were processed holistically, whole face masks should be more disruptive to performance than masks only comprising facial features. They found selective impairment of face matching when whole face masks were used, whereas matching of inverted faces, words and houses was disrupted equally by part and whole stimulus masks. This is also consistent with the notion that facial features are coded in parallel, at least to some degree (e.g., Sergent, 1984; Smith & Nielson, 1970).

In addition, if faces are perceived as a whole, rather than analytically/ componentially (as proposed for non-face objects in several models of object recognition; e.g., Biedermann, 1987, Hoffman & Richards, 1985; Marr & Nishihara, 1978), this would also involve the integration of configural information in the representation. That is to say, the spatial relations of the individual features are coded together with the facial features, per se (i.e. Rhodes, 1988; Young, Hellawell, & Hay, 1987). This contrasts with what would be expected for non-face objects in conventional object processing models. For example, according to Biedermann's (1987) influential *recognition-by-components* (RBC) object recognition theory, the to-be-perceived object would be decomposed into separable features, and then coded early and independently in the processing stream. Subsequently, the spatial configuration of the individual features would be specified, from a *viewpoint-independent* perspective, and input from these two stages would be matched against stored representations in object memory.

Further support for holistic processing effects has been demonstrated from a number of sources. Firstly, extensive behavioural evidence has been presented. For example, Tanaka and colleagues' (Tanaka & Farah, 1993) p*arts-wholes paradigm*, has been described above. The *face inversion* effect (e.g., Yin, 1969; McKelvie, 1995; for reviews, see Lipp, Price, & Tellegen, 2009; Valentine, 1988) where efficient recognition of facial identity or expression is disrupted by stimulus inversion (also see Chapter 4 below, for detailed discussion of face inversion effects), has also been taken as evidence for holistic representation of the upright face. In addition, *composite effects* (e.g., Young et al., 1987; see also Hole, 1994; Le Grand, Mondloch, Maurer, & Brent, 2004) and *spacing effects* (e.g., Freire, Lee, & Symons, 2001; see also Leder & Bruce, 2000; Le Grand, Mondloch, Maurer, & Brent, 2001; Mondloch, LeGrand, & Maurer, 2002; but cf. Yovel & Kanwisher, 2004; Youvel & Duchaine, 2006) are taken as illustration of the sensitivity of face processing mechanisms to misalignment of upper and lower face halves, and minor changes to spatial arrangement of features, respectively. These two effects are demonstrated by comparing performance in upright versus inverted stimulus presentation, given the prediction that performance is selectively impaired when efficient holistic processing is disrupted by inversion. Moreover, these effects provide converging evidence that spatial configuration of features is coded in holistic facial processing, although individual processing of features is not.

Moreover, additional support for holistic processing of faces is provided by neuroimaging studies. Face-selective fusiform activation has been reported in studies since the early 1990s (e.g., Sergent, 1991) and this response appears lateralized, with greater activation in the right hemisphere than the left. This brain region has also been shown to respond to a wide variety of stimuli presenting facial information (i.e. Cartoon, animal, Mooney faces and facial representations; see Kanwisher et al., 1997; Tong et al., 2000; O'Craven & Kanwisher, 2000; Cox, Meyer, & Sinha, 2004). In particular, this is also consistent with proposed hemispheric specializations for analytical (left hemisphere) and holistic (right hemisphere) processing mechanisms (see Davidoff, 1982; Young & Ratcliff, 1983; for reviews).

Although the FFA is associated with facial recognition (e.g., Kanwisher et al., 1997) and other fixed aspects of facial stimuli, that is not to say holistic processing is precluded in other face-specific regions (i.e. the STS and IOG). The functional dissociation between identity and expression processing (e.g., Hoffman & Haxby, 2000) has also been indicated in studies examining the neural correlates associated with face recognition or matching tasks (see Grill-Spector, et al., 2004; and Yovel & Kanwisher, 2005; respectively). However, although both FFA and STS have demonstrated reduced activation following facial inversion (Yovel & Kanwisher, 2005), this effect appeared somewhat unreliable across participants.

1.3.4.2 *Expertise effects: More than faces?*

The debate regarding face-specific holistic processing and a more generalized expertise phenomenon was inspired by Diamond and Carey's seminal work (1986), and continues to date (e.g., Tarr & Gauthier, 2000; McKone, Kanwisher, & Duchaine, 2007). This study famously explored whether other classes of objects, with which observers had substantial expertise, elicited equivalent configural processing to that demonstrated with faces. In this instance, participants were dog experts with long-standing experience of acting as dog-show judges. Subsequent testing with the inverted "expert" stimuli (i.e. the breed of dog each participant was an expert in) elicited equivalent inversion effects to that normally shown with facial stimuli. This contrasted with the absence of selective impairment following stimulus inversion for dog “novices”.

Placing *real world* expertise into a laboratory setting, Gauthier and colleagues (Gauthier & Tarr, 1997; Gauthier, Williams, Tarr, & Tanaka,1998; Gauthier & Tarr, 2002) trained participants with an artificial object class, the *Greeble,* which they used to simulate equivalent processing demands as face recognition (e.g., unique names, family membership, sex). This led to claims of holistic/configural processing effects with these stimuli, arising from both behavioural (Gauthier & Tarr, 1997; Gauthier et al.,1998; Gauthier & Tarr, 2002) and neurophysiological (Gauthier, Skudlarski, Gore, & Anderson, 2000), Tarr & Gauthier, 2000; Rossion, Curran, & Gauthier, 2002) data. However, the strength of this evidence remains somewhat contentious (e.g., McKone & Kanwisher, 2005; McKone et al., 2007).

Subsequent studies have not substantiated the claims of Gauthier and colleagues; with failures to replicate face-characteristic processing effects with Greebles (e.g., Gauthier & Tarr, 1997; Gauthier et al.,1998; Gauthier & Tarr, 2002), and a lack of extension of trained expertise to new Greebles (Gauthier & Tarr, 1997). Moreover, no clear evidence of everyday expertise producing face equivalent configural processing has emerged since Diamond and Carey’s original study (1986; and cf. Robbins & McKone, 2007; see McKone & Robbins, 2007; for further discussion). In fact, counter evidence from more recent neuroimaging studies has shown activation in object-selective brain regions with increased object expertise, rather than face-selective regions (see Moore, Cohen, & Ranganath, 2006; Op de Beeck, Baker, DiCarlo, & Kanwisher, 2006; Yue, Tjan, & Biederman, 2006).

This is particularly important since cortical areas commonly associated with face-selective activation (i.e. the FFA) have also been linked to expertise effects with other non-face objects. (e.g. Gauthier et al., 2000, 1999; but cf. Grill-Spector et al., 2004; and see McKone et al., 2007; for a review). However, that is not to say that expertise effects do not play a role in face processing phenomena. For example, the *other race effect*, where reduced holistic processing is demonstrated for faces of different racial origins than one's own (e.g., Rhodes, Brake, Taylor, & Tan, 1989; Valentine & Bruce, 1986), is a possible outcome of greater familiarity with one class of facial stimuli than another.

Although evidence supporting expertise effects as a unifying explanation for face-selective cognitive mechanisms is weak, this does not weaken the overall case for specialized face cognitive processing, per se. The wealth of support for holistic processing for faces (see Section 1.3.4.1 above), within a number of paradigms (i.e. part-whole tasks, face inversion, composite and spacing paradigms) appears robust, especially in conjunction with face-selective neural correlates (i.e. activation in the FFA, in response to a wide range of facial stimuli; Kanwisher et al.; 1997). Moreover, although much of this literature focuses on the recognition aspect of face processing (e.g., Young et al., 1987; Tanaka & Farah, 1993), discrimination of facial affect may also be facilitated by mechanisms that evaluate faces as a gestalt whole (see Section 1.3.3 above, for details of preferential processing of facial affect). This might be considered particularly pertinent in circumstances where processing of component facial features has been examined; for example, with schematic facial stimuli (e.g., Purcell & Stewart, 2006), or focus on specific features for specific affect (i.e. eye or mouth regions; e.g., Tipples, 2007; Fox & Damjanovic, 2006).

1.4 The emotional face: What is being processed?

Another important dimension, when considering the impact of the emotional face, is its actual affective content and the behavioural impact of *that* content. Although considerable evidence has been amassed in respect of facial processing overall, and specific properties of the face as a stimulus (i.e. the attentional properties described above, and in Chapter 3), this is arguably irrelevant if there is no understanding of what facial affect conveys to the observer. In turn, this means that behavioural cognitive, neuropsychological and electrophysiological evidence will be of less importance in this section, and a more philosophical and social psychology perspective will need to be adopted.

1.4.1 *What is a facial expression?*

> "Everyone knows that grief involves a gloomy and joy a cheerful countenance…there are characteristic facial expressions which are observed to accompany anger, fear, erotic excitement, and all the other passions…"
>
> Aristotle (nd/1913, pp 805,808)

At first glance, this seems a straightforward question to answer. A facial expression is simply a facial display; but of what, exactly? A traditional view encapsulates the concept of a particular facial muscle configuration, shaped to some degree by evolution, which communicates the emotional state of the individual (e.g., Darwin, 1872/1965; Ekman, 1972, Izard, 1997). Ekman's influential *neocultural theory* (1972, 1973) suggests that specific emotions and specific facial expressions are inextricably bound together; so that, with the occurrence of that emotion, the corresponding facial display is made. This expression is automatically generated by a hard-wired coupling of emotional states and motor responses (i.e. *a facial-affect program;* e.g., Tompkins, 1962; Ekman, 1972), which is then *universally* understood to convey the internal emotional state. This latter point is discussed in more detail below.

However, many theorists would contend that this construction is over-simplistic. For example, the notion of *display rules* (i.e. Ekman & Friesen,1969; Klineberg, 1938, 1940*)*, where social demands motivate humans to mask or distort their expressions in some way, means that emotion communication may not be the single, or primary, function of the facial expression. In fact, Fridlund (1992, 1994, 1997) asserts that *feelings*, as the putative emotional component of expressions, should be precluded from what is an exclusively socio-centric mechanism (see also Fernández- Dols & Ruiz-Belda, 1997). Insofar as facial displays can also be seen to regulate human interaction (e.g., the *behavioural ecology view*; Fridlund, 1994, 1997), they should, in addition, serve the individual's social purpose. Therefore, any conceptualization must include behavioural intentions and action requests (e.g., an angry expression would indicate that some form of aggressive act is likely to take place, and that the *Displayer* wishes the *Displayee* to withdraw).

In terms of distinguishing facial displays of emotion from other non-verbal behaviour, three criteria have been proposed (e.g., Frank et al., 1993); although these may also apply to other forms of emotional communication (i.e. emotionally-demonstrative vocalizations or movements). Firstly, an emotional expression has a comparatively short time course, given the complexity of the behavioural information that might be transmitted (i.e. 1-10s for facial displays; Bachorowski & Owren, 2001; Bchorowski, Smoski & Owren, 2001; Ekman, 1993). Secondly, facial expressions are elicited by *involuntary* muscular actions, which cannot be produced "to order" and arguably, cannot be suppressed easily, even under instruction (i.e. Dimberg, Thunberg & Grunedal, 2002; Kappas, Bherer & Thériault, 2000; Eisenberg et al., 1989)[3]. Lastly, facial expressions should have homologues in other similar species; which point is reminiscent of Darwin's (1872/1965) "systematic" investigations into the universality of facial expression, and will be discussed briefly below (see Section 1.4.2.1 below).

However, broadly speaking, many theorists (see Keltner & Ekman, 2000, Russell 1994, 1995; Hortsmann, 2003; for more detailed review) would now accept that a complex composite process underlies the production of facial expressions, comprising emotional phenomenology, characteristic physiological events and projective behavioural elements (e.g., Russell & Bullock, 1986; see also comment below in respect of the *Facial Expression Program*). More importantly, to support the argument that a group of negatively valenced facial expressions are accorded some form of adaptive preferential processing in the observer (i.e. Öhman, 2003; Öhman et al., 2001; Fox et al., 2000), it would be necessary for a complex array of likely antecedents and outcomes to be understood from a relatively brief facial display.

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[3] but see also Ekman, Levenson, & Friesen, 1983; Levenson, Ekman, & Friesen, 1990; Frank, 1988; Rinn, 1984; to contrast findings regarding *facial actions* which *can* be produced deliberately.

However, this is not to say that *there is* agreement about the affective content displayed in emotional faces, or that pan-cultural recognition of expressions is accepted (see Russell, 1994, for a review). This point is particularly relevant when empirical investigations present any kind of emotionally valenced facial stimuli. That is, the requirement that the intended affective message of a facial expression should be communicated without equivocation is too important to be assumed; certainly, not without evaluating the evidence.

1.4.2 *Facial affect: What is shown and how is it understood?*

1.4.2.1 *The universality hypothesis*

The long tradition of enquiry into human emotion, and particularly its facial display, is often crystallized into debate surrounding Darwin's (1872/1965) investigation into the expression of emotions across human and non-human species. Although his original notions of the transmission of acquired characteristics in this domain might appear redundant, using his work as a starting point for evaluating the universality of facial expressions (i.e. how far they are displayed and understood transculturally) is more straightforward. That said, it should be acknowledged that this concept predates Darwin by some time, potentially preceding even Aristotle (see Russell, 1994; for a summary of the history of enquiry into facial expression). Moreover, some critique of his methodology and conceptualization of emotion and facial expression is difficult to avoid (e.g., Izard, 1972; Ekman et al., 1972; see Russell & Fernández-Dols, 1997; Russell, 1994; for reviews).

However, Darwin's work has enjoyed a renaissance through the emergence of the *Facial Expression Program* (FEP) in the 1980s. This corpus can be described as presenting an expansive and rounded framework for understanding emotion, its display, and its communication to other humans (see Russell & Fernández-Dols, 1997, for an overview of the history and main theoretical perspectives of the FEP). Through this system of assumptions and theoretical perspectives, it has been possible to distil three key propositions for universality of facial expression:

i) Equivalent patterns of facial movement are observed across all human cultures.

ii) Observers will universally attribute the specific emotional content of the display to these patterns of facial movement.

iii) The facial displays are a veridical representation of those emotions across all human groups.

Russell and Fernández-Dols (1997) suggest that the last of these premises has been overlooked, despite the fact that supporting evidence is much needed (i.e. over-lapping evidence for propositions 1 and 2 remains largely independent of proposition 3). In contrast, high correspondence in facial expression across cultures has frequently been assumed, to the extent that is often taken for granted. However, review of the literature is particularly illuminating on this point. In fact, it has been said that the inconsistency of the literature means that "… there is now no evidence that, in a number of different societies, happy people smile, angry people frown, disgusted people wrinkle their noses, and so on." (Russell & Fernández-Dols,1997; p15; Russell, 1995; see also Fernández-Dols & Ruiz-Belda, 1997; Frijida &Tcherkassof, 1997; for further discussion). To say that this assertion throws the evidence for universality in facial expression into disarray is an understatement.

However, investigation into the second count has flourished (e.g., Winkelmayer, Exline, Gottheil, & Paredes, 1978; Boucher & Carlson, 1980; Ekman & Friesen, 1986; Ekman & Heider, 1988; Matsumoto, 1992). In a meta-analysis conducted on cross-cultural facial expression judgement studies (i.e. comparing Western literate, Non-Western literate and isolated illiterate communities; see pp107-109 for details of the studies analysed), Russell (1994) standardized the task for reliable comparison. Under these conditions, he found remarkable consistency for attributing the correct emotions to a given facial expression (i.e. approximately 80% or over correct responses for each of happiness, anger, surprise, fear and disgust) for Western literate populations. For Non-Western literate populations, the correct recognition scores dropped significantly, to a mean score of approximately 70% across all expressions. Lastly, isolated illiterate communities scored around 50% for all expressions, except for the happy display, which achieved approximately 90% correct recognition.

There are three particular points of note from this meta-analysis. First, statistically speaking, correct recognition was above chance for all but three expressions (all from the isolated illiterate population). This shows an appreciable consistency across a number of studies and a number of cultural contexts. Secondly, happy expressions were identified particularly well across all three groups, with 85 -95% accuracy. In contrast, all negative expressions were recognized less accurately in all groups, with considerable variability between both groups and expressions. This suggests that a) it is relatively easy to distinguish a smiling face from other expressions; b) this may be evidence of a facilitated ability to make broad positive/negative emotional discriminations in respect of facial stimuli (i.e. Section 1.3.3 above), and c) it is relatively difficult to differentiate between classes of negative expression (see Wagner, MacDonald, & Manstead,1986; Russell, 1997).

In addition, and thirdly, Russell himself points out the residual methodological differences that may impact on these findings. For example, photographic stimuli necessarily capture an exaggerated form of the facial expression, which may not be an accurate representation of the expression in the real world (e.g., Rinn, 1984; Skinner & Mullen, 1991; Reuter- Lorenz & Davidson, 1981). In addition, *forced-choice* experimental formats give participants labels for the facial displays, which could be taken as a form of demand characteristic (see also Fridlund, 1992; Kelter & Ekman, 2000). Thus, the labels given may not accurately reflect conceptualization of the stimulus shown (i.e. participants may choose labels on the basis of likelihood rather than authenticity, or categorize according to the labels rather than their internal construction of the facial expression). Lastly, potential confounds such as experimenter influence (see Sorenson, 1975) or simple design differences (i.e. within-participants versus between-participants designs) may account for a considerable amount of variability in the data. Russell (1994) found an 11% increase in correct recognition when a within-participants design was used in preference to a between-participants one.

Understandably, these issues have led to continuing discussion (e.g., Russell, 1994; 1995; see Izard, 1994; Ekman, 1994 for alternative analyses based on the

Table 1.0.1 Requirements of *minimal universality*. (In Russell & Fernández-Dols,1997; p17; see also Russell, 1995)

	Assumptions
1	Certain patterns of facial muscle movement occur in all human beings.
2	Facial movements are coordinated with psychological states (actions, preparation for actions, physical states, cognitive states, and other psychological conditions).
3	Most people everywhere can infer something of another's psychological state from facial movement, just as they can from anything else tat other person does.
4	People in Western cultures have a set of beliefs in which specific types of facial actions are expressions of specific types of emotion.
	Caveats
1	Facial actions are not necessarily signals.
2	Facial action is not necessary or sufficient for emotion. Facial action is not necessarily more associated with emotions than with other psychological states.
3	What inferences are made in one culture, or by one individual, need not coincide exactly with inferences made in another culture or by another individual.
4	People in all cultures need not share Western beliefs about the specific associations of emotions and facial actions.
5	Western beliefs about the association between facial expressions and emotions are not necessarily valid.
	Predictions
1	Photographs of facial movements will be associated with psychological state with agreement that is greater than chance.
2	People are sometimes accurate in the inferences that they make on the basis of facial movements.
3	There will be similarities across cultures in what is inferred from facial movements.

information above, and van Brakel, 1994; Cornelius, 1996; Oatley & Jenkins, 1996 and Parkinson, 1995; for alternative reviews). However, a tentative consensus has been reached in the notion of *minimal universality*. This term might be interpreted as minimizing the possibility of pan-cultural understanding and production of facial expression.

However, Russell (1995; see also Russell & Fernández-Dols, 1997) asserts that it should be taken more as an indication that this universality exists at least to the degree suggested by the tenets of minimal universality (see Table 1.1, above). Moreover, he asserts that this can be taken a measure of cross-cultural similarity in interpretation of facial expression, without the prerequisite of an innate mechanism of emotional signalling. Thus, the most important question for modern research may be; how far beyond *minimal universality* does human understanding of facial expression reach?

1.4.2.2 *What are basic emotions?*

The question of the affective component of facial expression is often evaluated through the concept of *basic emotions*. These comprise the essential "building blocks" of all human facial affect (e.g., Ekman, 1999, 1972; Plutchik, 1980) in terms of its underlying emotional content, and are thought to number seven emotions (plus or minus two; e.g. Ekman, 1972, 1992, 1993). Facial expressions that fall outside this category are suggested to be formed from a combination of two or more of the basic emotions listed below. One legacy of the *FEP* (see Section 1.4.2.1 above) is a robust and detailed conceptualization of basic emotions. These are thought to include *happiness, surprise, fear, anger, contempt, disgust and sadness,* although a clear distinction between *surprised* and *fearful* expressions is not held unequivocally (e.g., Russell, Suzuki, &

Ishida, 1993). In addition, some debate also persists over the inclusion of *contempt* (i.e. Ekman, O'Sullivan, & Matsumato,1991; Matsumato, 1992; Russell, 1991). Their direct relation to facial displays comes from the premise that any affective state, lacking its own unique facial signal, is not a basic emotion (e.g., Russell, 1997).

Moreover, under the auspices of the *FEP*, a basic emotion is held to be pan-cultural (i.e. universal), genetically governed and discrete (i.e. any emotions, other than those designated as basic, are combined to form combined emotional states, similarly to the blending of facial expressions). In addition, a psychological state corresponding to a basic emotion comprises i) an internally consistent and characteristic pattern of facial behaviour, ii) a unique and conscious subjective experience, and iii) distinctive physiological/ motor correlates. Particularly noteworthy are the absence of any cognitive element (cf. Schacter & Singer, 1962; Isen, Shalker, Clark, & Karp,1978), and the parallels that can be drawn with the component parts of the facial display itself (see Section 1.4.1 above).

With an interesting return to Darwin's basic principles (1872/1965), another important aspect of basic emotion communication is that the *encoding* and *decoding* (i.e. production and recognition) of these expressions constitute a signalling system (e.g., Ekman, 1971; Izard, 1971; see Andrew, 1963 for an evolutionary view). This is held to be an adaptive response to the experiential complexity of existence as a socially sophisticated species (i.e. one that requires a level of socio-emotional adeptness to function fully; e.g., Pascalis & Kelly, 2009; Carey, 1992). However, despite its apparent humano-centric focus, this assertion would predict a level of similarity in facial display and expression configuration across species (e.g. Darwin, 1872/1965, but see Pascalis & Kelly, 2009; for further discussion).

In summary, and with clear parallels to the constituent parts of facial expressions (see Section 1.4.1 above), basic emotions are believed to comprise aspects of psychological state and closely-associated physiological/ action-based responses. Moreover, each of the basic emotions can be directly mapped onto a distinct facial display, which in turn, is held as characteristic of the correspondent underlying emotion. Perhaps most importantly, these emotions are suggested to exist across species to some extent, and are the product of adaptation to the life experiences of a socially-complex animal. This is reflected in a highly coherent system of emotional/ expressional production and understanding, which may be defined as *minimally universal* (see Russell, 1995, 1997, and Section 1.4.2.1 above). Overall, this suggests a level of confidence in the fact that facial stimuli presenting a clear expression of a basic emotion will be processed and understood in a consistent manner across participants, regardless of culture and individual difference.

The next chapter will demonstrate a striking change of subject matter. Given that the investigations detailed in Chapters four to seven will adopt two paradigms (i.e. *visual search* and *preview search*; Watson & Humphreys, 1997) drawing on attentional mechanisms, the following chapter will focus on this area of cognition.
It will outline relevant theoretical perspectives on visual attention in general, and those pertinent to *visual search* and *preview search*, in particular.

Chapter 2

Visual attention and selection

“The attention, they say, assists in all that goes on in man….The attentive function of the rational soul, in fact, pervades in all the powers without exception – the rational, the irrational, the vegetative….for this function is conversant with the faculties- both the cognitive and the vital. In so far as it is conversant with the cognitive energies it is called Attention.”

John Philoponus

(translated by Hamilton, 1895, p 942,)

2 Visual attention and selection

2.1 Overview

Chapter 1 focused on those mechanisms underpinning the processing of faces in general, and facial expression in particular. This chapter addresses the visual attention background to this thesis; literature that supports both the main paradigms that will be used in Chapters 4-7 (i.e. *visual search* and *preview search*; Watson & Humphreys, 1997), but also provides the experimental context for the final introductory chapter, examining visual search with emotional faces. Thus, the following chapter will review the most relevant theories, paradigms and attentional mechanisms that are important for the empirical work that follows.

A final consideration is the overlap of subject matter with subsequent chapters. As mentioned above, some aspects of the literature reviewed here will obviously share theoretical perspectives and evidentiary themes with Chapters 3-7. To avoid repetition and maintain focus on each individual empirical chapter, this chapter will examine the general attentional mechanisms that are important hereafter. Specific aspects of the literature that are pertinent to particular experiments will be presented in those chapters, rather than here.

2.2 Visual attention and selection

The notion of selection in visual attentional processes is not immediately a straightforward one. Despite the overwhelming array of to-be-perceived (or, to-be-attended-to) stimuli presented to us in the visual field at any given moment, our subjective experience is that we process it all. Yet for this to be true, it would require a visual system capable of operating without performance limits and a brain that could successfully utilize this information (without being paralysed by a profusion of signals, or distracted by irrelevant data). The alternative is that some form of selection must take place (i.e. a process that allows us to attend to some items, whilst ignoring others), in order for us to function efficiently.

Thus, despite continuing debate within this field as to *how* and *when* selection actually takes place, its necessity as a function is not questioned. To paraphrase James' (1890/1950) definition, the essence of attention is *concentration or focus upon sensory information relevant to the individual* (for whatever reason) *within the visual field*. And this distils our concept of selection neatly. How this concentration or focus is applied to visual inputs, could be said to rely on how attention enables us to distinguish between competing stimuli. And in turn, this allows us to examine selection processes in more detail.

This review will explore some of these attentional mechanisms in more depth (e.g., exogenous / endogenous control of attention, attention capture, negative priming, inhibition of return). In addition, it will briefly review the theories proposed to underpin processing in spatial selection (for example, classical perspectives on visual search; Treisman & Gelade, 1980; Wolfe, 1994; Wolfe, Franzel, & Cave, 1989; Duncan & Humphreys, 1989) Lastly, it will focus upon one particular aspect of selective attentional processing; time-based selection, and the theoretical issues surrounding the processing advantage that emerges when observers preview a subset of stimuli from their subsequent search (i.e. *the preview benefit*; Watson & Humphreys, 1997; 1998).

2.2.1 *The locus and nature of selection in attention*

2.2.1.1 *The early versus late selection debate*

Although this chapter will not dwell on the various theories surrounding the point at which selection is made in attentional processing, it is useful to summarize these before examining the mechanisms by which selection might take place. The debate concerning the locus of selection is broadly dichotomized into an *early* versus *late* selection standpoint. However, both standpoints assume a "bottleneck" of processing at some point in a limited-capacity processing stream.

Broadbent (1958) was the first proponent of an early selection mechanism or *filter theory of attention*; whereby sensory information was temporarily buffered, before a selective filter (attuned for basic stimulus features, such as colour, pitch or location) enabled relevant information to pass to the processing channel. Treisman (1960) elaborated this model to account for the fact that attentional selection often permitted distracting factors to intrude upon subsequent processing. Her *filter attenuation theory*, suggested that the early selection filter does not exclude all unattended material; it weakens it to the point that it will only reach consciousness if it matches (approximately) the criterion set for full stimulus processing.

Conversely, researchers such as Deutsch and Deutsch (1963) and Norman (1968) have argued that processing limitations do not impact until the categorical level of processing and thus, early selection is not necessary. Accordingly, they have asserted that attention is not required to process sensory input for perceptual and identification purposes. Attention is necessary only when a more enduring representation of the input is required; all sensory input is processed up to that point, but decays quickly, in the absence of this consolidation.

Lastly, whilst both theoretical views have continued to be debated, and discussion has included factors which may impact on the locus of selection (e.g., *Perceptual Load*; Lavie & Tsal, 1994, Lavie, 1995, Treisman, 1969); flexibility in the selection mechanism has also been emphasized. Johnston and Heinz (1978) proposed that selection can take place at any point in the processing stream, dependant on task demands and cognitive resources. They suggest that demand on cognitive resources will increase as processing continues; and thus, unattended/irrelevant information will be filtered according to the nature and resource-demand of the particular task

2.2.2 *What is selective attention for?*

In terms of a theoretical framework, it might be more relevant to consider the purposes that selection in visual attention may serve, rather than become enmeshed in the historical debate over the locus of selection in the processing stream. Three broad distinctions can be made here, largely on the basis of the purpose for which information from the selection process is construed. More interestingly, it is clear that these distinctions are not the product of modern science; instead, they have emerged from a long tradition of philosophical enquiry and early psychological investigations.

2.2.2.1 *Selection for perception*

[Things are not seen sharply]

"…save for those for which the mind has prepared itself."

Lucretius (1965/1967, IV.803-804)

Firstly, given the suggested capacity limitations of visual perception (e.g., Kahneman & Henik, 1982; Treisman, Kahneman, & Burkell, 1983; Neisser, 1967), it may be that attention subserves the perceptual system by selecting those items in the environment that will go on to be fully perceived (i.e. an *object-based view*, in Duncan's terms, 1984). The absence of such a selection mechanism would leave the perceptual system vulnerable to overload; in a manner broadly consistent with the rationale behind the early selection perspective (e.g., Broadbent, 1958). An alternative rationale emerges from a theoretical standpoint that involves the decomposition of objects into their component low-level features (e.g., Treisman & Gelade, 1980; *feature integration theory*) before their reconstruction into full object representations, once focused attention has been applied. In this case, without the operation of an attentional mechanism that restricts perceptual processing to a specific location, the combination of all possible features from objects in the visual field, in all possible configurations would result in an unmanageable *binding problem*.

2.2.2.2 *Selection for awareness*

> "Even in things that are plainly visible you can note that that if you do not direct the mind, the things are, so to speak, far removed and remote for the whole time…"
>
> Lucretius (IV.811-813)

A second view of the purpose of selective attention takes a step beyond perception of an item. Here, selection would enable perceived items to be brought to conscious awareness. This would be distinguished from those unattended items that are processed visually, perhaps to the point of semantic identification, but have not yet been "registered" consciously. This could be seen as falling within a Jamesian view of *anticipatory preparation*, or *preperception* of a yet-to-be-perceived object (1890/1950; see also Wundt, 1907b).

2.2.2.3 *Selection for action*

Thirdly, some commentators have argued that considering the operation of selection within visual domain alone is too restrictive; instead, the effects of selective attention cross modalities, and are used to constrain the range of actions possible from sensory inputs. This perspective rests upon the fact that, despite the number of potential sensory inputs at any given moment, typically, motor effector systems are limited to a single action response (e.g., Allport, 1987). Moreover, a Gibsonian approach (e.g., Gibson, 1979, 1966) suggests that attentional selection is required to prevent "… the behavioural chaos that would result from an attempt to simultaneously perform all possible actions for which sufficient causes exist." (Neumann, 1987; p 374). Thus, resource limitations in attentional processing might be attributed to the selection of an appropriate action output, rather than, for example, perceptual processing limits.

2.2.3 *Spatial selection in visual attention*

Spatial selection might be thought of as the means by which we select which objects in our visual environment we attend to as part of everyday tasks (e.g., finding a specific car in a crowded car park, or locating a set of keys). By this, we can conceptualize a process that allows us to allocate attention to a specific item amongst the vast number of objects existing in the space around us. Note that, although this has been phrased to suggest that *top-down* or intentional expectation/ experience- based processing is at work (e.g., Di Lollo, Kawahara, Zivic, & Visser, 2000; Folk, Remington, & Johnston, 1992), this is not necessarily the case; properties of the objects evident in the environment can also control how our attention is deployed (i.e. *bottom-up*, stimulus-driven processing; e.g., Theeuwes, 1991, 1992, 1994; Abrams & Christ, 2003; Rauschenburger, 2003). This distinction will be explored in more detail below (see Section 2.2.8.1).

That said, suggesting that selection may be for purposes of awareness or perception reminds us that it is rare to consciously recognize that we are not attending to every object visible in the real world. Indeed, reality may be far from this. For example, Duncan (1984) suggested that, although many objects may be processed prior to our attentional engagement (i.e. preattentively), effectively segmenting the visual field into objects on the basis of their low-level properties (i.e. spatial proximity, colour, motion), we are only able to allocate focal attention to one item at a time. Thus, the first question we might ask is: How does attention operate to select that item?

2.2.4 *A metaphor for attention: The attentional spotlight*

A straightforward metaphor for the operation of attentional selection is that of a spotlight (Eriksen & Hoffman, 1973), that can highlight one region of space, and apply attention only to those items falling within that spatial field. Originally, this “spotlight” was understood to be of fixed size and resolution, without the flexibility to focus on one item within a perceptual group (Eriksen & Eriksen; 1974). However further research identified more flexibility within the mechanism; for example, the ability to focus in on a single letter of a larger word (LeBerge, 1983; see also Eriksen & Yeh, 1985; Eriksen & St James, 1986).

LeBerge's findings (1983) also highlighted the ability to "zoom" into a particular aspect of a stimulus (for example, the middle letter in a five letter word) and the impact this had on attentional resolution. In this instance, LeBerge found that if priority was given to a single letter, processing of letters outside that focus was impaired. In contrast, where focus was given to the entire word, all letters were processed equally effectively. In turn, this led to the comparison of the selection mechanism with a zoom-lens, (Eriksen, 1990); the focus being adjusted according to task demands, and attentional resources being deployed according to that focus. Resolution was also related inversely to the width of the focus; i.e. when attentional focus was wide, resolution was low, and vice versa.

However, contemporary evidence suggested that the spotlight metaphor was over-simplistic. For example, when Neisser and Becklen (1975) superimposed two scenes in a display, they found that observers could preferentially attend to one scene over the other. This explicitly contradicts the attentional spotlight or zoom-lens, as in that case, the same spatial field would imply the same processing focus/ attentional resources.

Moreover, it might be said that the spotlight metaphor is suggestive of a serial mechanism, moving attention from one location to the next, in turn (see also Eriksen & Webb, 1989). However, other evidence indicates that when items can be grouped according to a shared perceptual feature, attentional selection can be made on this basis (i.e. colour, orientation, motion, texture or similarity; Treisman & Gelade, 1980;

Nakayama & Silverman, 1986; Duncan & Humphreys, 1989; Bravo & Blake, 1990). An alternative to a more sharply defined attentional spotlight was proposed by LeBerge & Brown (1989). This comprised the notion of a spatially-applied gradient of attentional resources, where resources were more highly concentrated in the centre (falling off towards the edges), and which could vary in size. LeBerge and colleagues (1989) also proposed that deployment of resources could also be the product of prior attentional activity; that is, resources can both accumulate or decay on a spatial basis (see also LeBerge, Carlson, Williams & Bunney, 1997). Thus, despite the simple intuitive appeal of the spotlight metaphor, understanding of selective attention appears to have significantly outgrown its comparison with either a spotlight or zoom lens.

2.2.5 *The visual search task*

One method by which visual selection processes can be systematically evaluated (for example, where a particular target is selected from our environment), is the visual search task. From one perspective, this is a paradigm that is straightforward to investigate (and manipulate) in laboratory-based studies. However, this task also encompasses the process by which we search for designated targets in our rich (and often, cluttered) visual environment, allowing us to investigate what specific elements of this environment make a particular search easy or difficult.

In these terms, it would be harder to identify a simpler, more *real world* example of the visual system in action. That said, the parameters of the search process per se, and the impact of associated processing (e.g., object representation, attention capture, preattentive processing), have been explored extensively in lab-based behavioural studies over the last 30 years. This provides an extensive literature by which to understand these basic mechanics of visual processing.

In essence, a typical visual search task might comprise detecting a particular target (for example, a blue vertical block) amongst a number of distractor items (for example, a group of green vertical blocks; but see Treisman & Gelade, 1980; for other examples of commonly-used stimuli).

a) Single feature search   b) Conjunction search

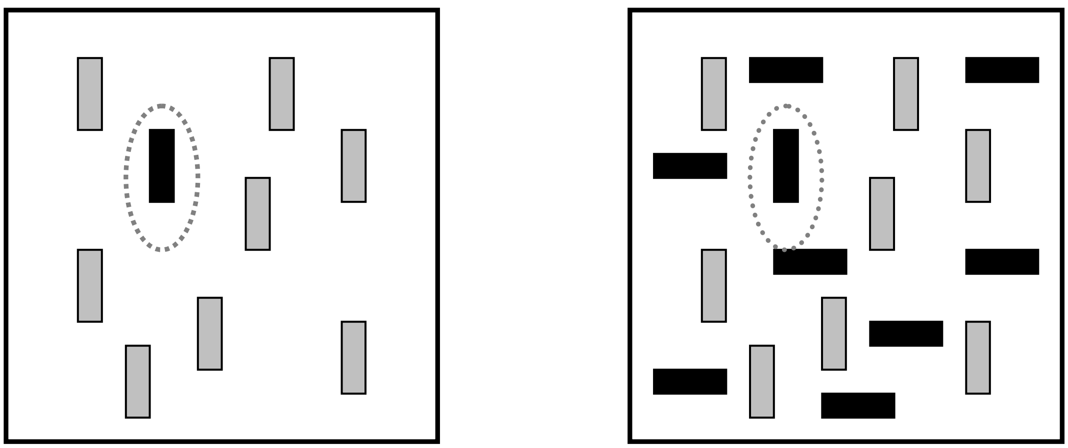


Figure 2.1   Examples of a visual search task

a) A single feature search task, where the target is distinguished from the distractor set by a single unique feature (i.e. colour).

b) A conjunction search task, where the target is defined by the conjunction of two or more features it shares with the distractor set (i.e. colour *and* orientation).

This would present a relatively straightforward search - in fact, given that the target can be distinguished from the remainder of the array on the basis of a single unique feature (for more details regarding basic features, see e.g., Treisman & Gelade, 1980; Treisman & Gormican, 1988; Treisman & Souther, 1985; Nothdurft, 1993; Sagi & Julesz, 1987; Wolfe, 2003; see Wolfe, 1998; for a review) the target would be expected to effectively "pop out" from the surrounding display (e.g., Treisman & Gelade, 1980; and see Figure 2.1 above). This presents a *single feature search*. Conversely, when the target is surrounded with distractors that, as a set, combine two or more of the target-defining features (or a *conjunction* of these low-level properties), the search becomes more difficult (see Treisman & Souther, 1985; but cf Wolfe, 1994). There is no longer the same sense of effortless target detection that one gets when a single feature makes our target distinct from the distractors around it (i.e. where the target "pops out").

Further manipulations include varying the total number of items displayed in a trial, whether the target is present or absent in the display, or the nature of the distractors presented (e.g., their degree of similarity to the target, or heterogeneity as a set). And, in turn, any of these manipulations might result in a harder or easier search – which would then be evaluated according to how search performance varies under the influence of each manipulation. Several highly influential models have been proposed to account for the relative ease or difficulty of some search conditions compared with others. However, before these are outlined, it is necessary to review some of the parameters of performance in visual search that these models utilize in their explanations.

2.2.6 *How can search be designated efficient or inefficient?*

Figure 2.1 above may give an intuitive “feel” for the relative ease of a particular search task; however, the parameters for efficient or inefficient search have been precisely defined. Whilst mean correct reaction times (RTs) may be used as a straightforward performance indicator, regressing RT data against increasing set size allows the derivation of a search slope function (for example, x ms/item). This serves two purposes; firstly, it allows search performance to be represented as a unit of time taken to search through that specific search context, per each additional item added to the display (i.e. a numerical measure of search ease or difficulty, per se). Secondly, it gives a measure of search efficiency that is directly comparable between different search conditions (i.e. Smilek, Eastwood, & Merikle, 2000).

a) Single feature search

b) Conjunction search

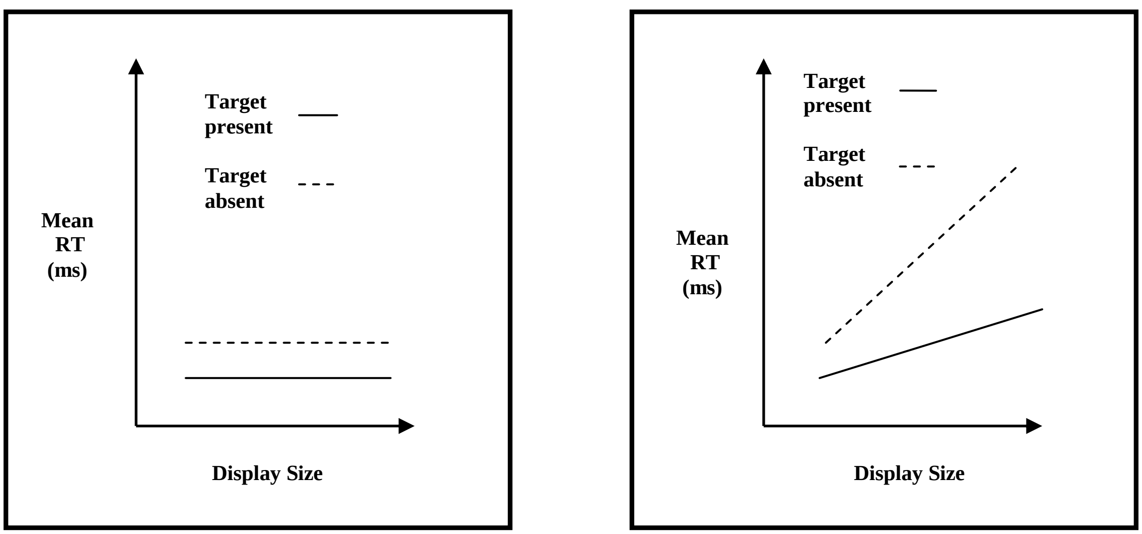


Figure 2.2 Examples of typical search slopes for single feature and conjunction searches, with target present and target absent trials shown separately

Figure 2.2 above shows typical search slopes for feature and conjunction searches (i.e. relatively easy and difficult search tasks, respectively).

These would typically demonstrate different search slopes if depicted individually (see Treisman & Gelade, 1980; for examples). Moreover, of particular note in Treisman & Gelade's seminal work (1980), whilst target absent and target present trials showed little or no overall difference in RTs (or search efficiency) in single feature search, a 2:1 ratio of search rates for target absent trials to target present trials was demonstrated in conjunction search. This is held to reflect the operation of a serial self-terminating search in conjunction search (i.e. a process that required exhaustive search through each item to verify whether it was the target, in the case of target absent trials).

Search slope functions with a value around 0 ms/item can be considered *very efficient* (i.e. RTs are independent of increasing set size), with values up to around 10 ms/item designated as *efficient*. Values between 20-30 ms/item are usually taken to indicate *inefficient* search, with those exceeding 30 ms/item suggesting *very inefficient* search (Wolfe, 1998). In turn, this categorization feeds into other concepts important for exploring the search mechanism. For example, where RT is not related to increasing display size, it is generally held to indicate that search is on the basis of a perceptual feature that is available preattentively (e.g., Treisman & Gelade, 1980; Treisman & Gormican, 1988; Treisman & Souther, 1985; see also Wolfe, 1998; and cf. Wolfe & Horowitz, 2004). Such features are suggested to include orientation, colour, size and motion (e.g., Treisman, 1985; Wolfe, 1994; Tresiman & Gormican, 1988; Sagi & Julesz, 1987).

Preattentive mechanisms are believed to operate where stimuli (or their component features) are processed independently of the current focus of visuo-spatial attention, without capacity limitation. In addition, these are held to operate in parallel fashion (e.g., Treisman & Gelade, 1980; Duncan, 1984; Kahneman & Henik, 1981; Treisman, Kahneman, & Burkell, 1983; Neisser, 1967) outside conscious awareness- and generally, elicit efficient search, when utilized in a particular search task (but cf. Joseph, Chun & Nakayama, 1997; who demonstrated that attention was needed for the detection of even basic features). In contrast, where search performance (RT) is positively related to increasing display size, this not only produces an inefficient search but also indicates the serial application of attention from one item to the next.

A subcategory of visual search methodology has been used frequently to establish whether a particular feature is processed preattentively, or as a *diagnostic for preattentive processing of separable features* (e.g., Treisman & Gormican, 1988; Treisman & Souther, 1985; Wolfe, 2001). The search asymmetry method evaluates search performance related to presentation of a given stimulus as a target (surrounded by another stimulus type, acting as a distractor set) and the reverse configuration. When the defining feature of an item is preattentively processed, it should result in target "pop out" when presented thus, but serial search when presented as the distractor set.

2.2.7 *Models of visual search*

The mechanisms underlying visual search have been minutely examined, resulting in a proliferation of empirical findings and a number of influential theoretical perspectives. Three models dominate the literature; *feature integration theory* (Treisman & Gelade, 1980), *attentional engagement theory* (Duncan & Humphreys, 1984), and the *guided search model* (e.g., Wolfe, 1994; Wolfe, Cave & Franzel, 1989). These models are outlined briefly below (but see also Wolfe, 1998; for a comprehensive review).

2.2.7.1 *Feature Integration Theory*

Feature integration theory (FIT; Treisman & Gelade, 1980) follows from a theoretical standpoint where "features come first" (Treisman, Sykes, & Gelade, 1977), and provides a conceptual structure for understanding how low-level features of an object might be combined to form a representation of that object. In turn, FIT also clearly predicts how this process would impact on search performance when searching through an array. Although Treisman went on to refine this theoretical framework throughout the 1980s and 90s (e.g., Treisman, 1992, Treisman & Sato, 1990; Treisman & Souther, 1985; Treisman & Gormican, 1988; Treisman et al., 1983; Treisman & Schmidt, 1982), her initial perspective proposed the operation of a selective mechanism that binds together features (e.g., colour, orientation, luminance) present at a particular location, using attention as the "glue" to form an object representation.

This conjunction of features was suggested to operate via specialized *feature maps*, upon which activation, corresponding to spatially free-floating features present in the visual field, is encoded. Individual f*eature maps* are proposed to exist for each basic feature and activation is coded early in the processing stream, although location information is not available at this stage of processing. The focus of attention applied to a specific location would bind all feature-based activation present within that spatial field, temporarily excluding those outside. Selection is made then, via the *master map of locations*, through which the activation coded in parallel across feature maps is accessed, upon the location-specific application of focal attention.

However, according to this model, not all searches would require features to be combined (or conjoined). For example, when a target could be distinguished from its surrounding distractors on the basis of a single feature, the presence or absence of that feature could be detected at the *feature map* level of processing. As FIT postulates this processing may occurring preattentively and in parallel, its operation would necessarily be rapid, resource- unlimited and outside conscious awareness. Search for a target that could be defined thus would, in turn, be highly efficient. In contrast, on occasions when a target cannot be detected on the basis of a single feature (i.e. where it shares two or more features with its distractor set), correspondingly, search would be more resource-intensive and less efficient. In this instance, features must be re-combined to form whole object representations in order to determine whether any individual item in the array is the target in question; and correspondingly, search will be more resource-intensive. Serial application of attention will be required at the location of each item in the field to make that decision, and consequently processing will be slower, terminating only when the target is found (or its absence is confirmed, after an exhaustive search).

In addition, FIT provides for alternative methods of feature conjunction, aside from instances when this processing is not required (i.e. where a target may be detected through preattentive processing of features). When object representations are conjoined from their component features, access to stored representations of a particular object may be available to lend top-down guidance for the correct recombination of those features (e.g., the sky would be represented typically as blue, but is unlikely to be yellow). Further, outside the focus of selective attention, other features present may combine spontaneously, but erroneously, demonstrating what is known as an *illusory* *conjunction* (for more detailed examination of illusory conjunctions, see Treisman & Schmidt; 1982) .

2.2.7.2 *Attentional Engagement Theory*

One alternative account of the mechanisms at work in visual search, and the resultant ease or difficulty of a given search task, relies upon the similarity of the stimuli comprising the search array. Duncan and Humphreys' (1989, 1992) *attentional engagement theory* construes this similarity in two ways; i) the similarity of the target to the surrounding distractor set, and ii) the similarity of the distractor set, within itself. In the case of both increasing target-distractor similarity *and* decreasing distractor-distractor similarity, their theory asserts that search performance will become less efficient.

The reasoning behind both of these effects lies within Duncan and Humphreys' conceptualization of the search mechanism itself. They suggest that, following initial preattentive encoding of all objects in the array, "successfully" selected information enters into *visual short term memory* (VSTM), and that the time taken for this selection to take place is reflected in overall search efficiency. Thus, if information relevant to a target in a particular search has been encoded, together with information from distractor items highly similar to this target; these representations will subsequently compete for VSTM selection, slowing the search process.

In addition, when distractor sets become less homogenous as a group (i.e. they display increased dissimilarity to each other), efficient rejection of this set on the basis of perceptual grouping is impaired. Similarly to the serial processing proposed under a FIT model of search, highly dissimilar distractor items will have to be examined on an individual basis to ascertain whether they can be rejected. In turn, this will reduce the speed and efficiency of the search process. Note however, that Duncan and Humphreys (1989) do not make the traditional serial/ parallel search distinction. Since their model hinges on ubiquitous preattentive processing in all search tasks, regardless of stimuli, the distinction becomes redundant.

2.2.7.3 *The Guided Search Model*

This model also emerges from the argument that the distinction between parallel and serial search processes is largely artificial. Instead Wolfe, with a number of colleagues, and over a decade of research (e.g., Wolfe et al., 1989, Wolfe, & Pokorny, 1990; Wolfe, Yee, & Friedman-Hill, 1992; Wolfe & Friedman-Hill, 1992 a,b,c; Wolfe,1993; Wolfe, Friedman-Hill, & Bilsky, 1994; Wolfe & Bennett,1996; see Wolfe, 1998; for a review), asserts that search performance and its underlying ease or difficulty, should be conceptualized along a continuum. He suggests that where a particular search task falls on this continuum, is governed by the level of preattentive processing, which subsequently acts to guide the deployment of visual attention to the search array. That is to say, parallel preattentive processing of the to-be-searched items effectively segregates stimuli on the basis of their likelihood to represent the target. In turn, this allows the efficient prioritization of likely targets in the array for subsequent search. For example, a search array containing a target blue A and distractor blue and green Hs, could be parsed into green and blue items preattentively (i.e. on the basis of their colour), enabling increased search efficiency.

In addition, Wolfe's theoretical standpoint can still speak to the more traditional distinction between parallel and serial search processes. Here, he argues that preattentive processing can still partition the search array on the basis of whether a given perceptual group it is likely to contain the target. Thus, the array is divided into likely targets and distractors, presenting a reduced number of stimuli to be searched serially (and increased overall search efficiency; cf. Duncan & Humphreys, 1989).

Moreover, Wolfe (1989) proposes that overall search efficiency can rely on the amount of information elicited preattentively. That is, when an array can be parsed on the basis of several features, this will lead to increased efficiency in detecting the target. For example, Wolfe has attributed the enhanced search efficiency when targets can be defined on the basis of a triple conjunction of features (rather than the standard two), to increased preattentive partitioning of stimuli. Conversely, a model such as Treisman & Gelade's FIT (1980) would predict impaired performance where additional resource is required to conjoin more features.

Another facet of the *guided search model* can be explained in relation to the classical division of tasks into single feature and conjunction searches, and the relative difficulty attributed thereto. Wolfe proposes that the salience (i.e. the contrast between local features) of a particular item can also contribute to the efficiency of the preattentive guidance. In a single feature search, the salience of the target will be high, resulting in a low signal-to-noise ratio within the visual system. Target detection in these circumstances will be particularly effective. However, in circumstances where the signal-to-noise ratio increases (i.e. where a target is less salient within an array- for example, in a conjunction search), search performance will be impaired and serial application of attention may have to be deployed, in addition to preattentive processes.

2.2.8 *The control of attention*

Although the mechanisms outlined above can account for specific processes at work during search itself, it is difficult to extend them to describe the control of attention more generally. For this, it is necessary to look at attentional control in its two forms: exogenous control (i.e. that arising from the nature of the stimuli themselves) or endogenous control; where the emphasis shifts to the expectations, intentions or strategies of the observer. This distinction also follows what we might refer to as *bottom-up* or passive, stimulus-driven control of visual attention (e.g., by attention capture) as opposed to an active, *top-down*, attentional set driven control; with the associated connotations of resource demand, capacity and awareness of processing that we would attribute to this distinction (see Ruz & Lupiáñez, 2002; for a review). These two forms of attentional control will be reviewed briefly, summarizing the main areas of debate.

2.2.8.1 *Exogenous control of attention*

Arguably, the most relevant example of stimulus-driven attentional control to this thesis is *attention capture*; whereby the properties of a given stimulus literally "capture" the observer's attention (e.g., Theeuwes, 1991; 1994; Yantis & Jonides; 1990, 1984; see Ruz & Lupiáñez, 2002; p 285, for a definition). Certainly, this phenomenon remains extensively researched to date, with much effort being given to establishing the precise conditions under which attention capture is elicited (see also; von Mühlenen & Lleras, 2007; von Mühlenen, Rempel, & Enns, 2005; Franconeri & Simons, 2003, 2005; Abrams & Christ, 2003, 2005, 2006; Christ & Abrams, 2008). However, authoritative work on this phenomenon was carried out over 25 years ago, with Yantis and Jonides' (1984) classical study on the effect of abrupt onsets.

Their task comprised a search for a specified letter target, which was created either by an abrupt onset at a previously empty location (i.e. by adding line segments), or an offset at a previously occupied one (i.e. by removing line segments from a figure-of-eight placeholder stimulus). The former involved an abrupt luminance increment, whilst the latter offset involved a luminance decrement in the respective location. In this instance, Yantis and Jonides (1984) found that when the target appeared as an abrupt onset, search performance was enhanced (i.e. search slopes were shallower than when the target was an offset), whereas when it was presented as an offset, search was selectively impaired. From these findings they asserted that an abrupt visual onset enabled attention to be automatically oriented to the target, presumably to facilitate subsequent search.

That said, given this paradigm, it was not possible to dissociate whether the abrupt onset received preferential processing as a purely physical phenomenon (i.e. a local luminance increment) or as an event with a privileged status (i.e. the appearance of a new item in the display). However, in examining these two potential sources of attention capture, Yantis & Hillstrom (1994) found that a luminance increment was insufficient to capture attention, without an associated new item onset; which led them to assert that the behavioural importance of the new item resulted in the search advantage (see also Miller, 1989; Watson & Humphreys, 1995; for investigation of partial onsets and offsets).

This finding has not been without controversy; Theeuwes (1995, 1991b), for example, has also investigated the effects of luminance increments in visual search. In Theeuwes' study, participants searched for a target that was of increased, reduced, or equal luminance to the surrounding display. In this instance, he showed that an abrupt increase of luminance was needed to accompany a new item onset, for that item to "pop out" in the display. Moreover, he demonstrated in other work (1991a; 1992; 1994) that luminance was not the only property that could influence a target's ability to capture attention; it could depend upon a target's perceptual salience amongst its distractor set. For example, where an irrelevant distractor item (or *singleton*, in respect of its defining feature) was present in the display, this item could impair search performance by capturing attention, provided its defining feature was of sufficient salience.

In any event, despite ongoing debate as to the precise conditions that elicit attention capture (see above), it appears clear that this phenomenon is sometimes essential to the control of visual attention. Moreover, the implication that stimulus salience and ecological considerations are relevant to its operation is also particularly pertinent. That is to say, indication that the orientation of attention is facilitated to stimuli (i.e. emotional faces) or events (i.e. new item onsets) with strong behavioural impact is important to the empirical work that follows.

2.2.8.2 *Endogenous control of attention*

In stark contrast, top-down, endogenous control of attention is said to be exerted actively over the stimuli in question, by the individual, in a manner dependent on their current *mental set*. Later work by Yantis and Jonides (1990), neatly illustrates the contrast between the two forms of attentional control. Accordingly, they suggest that the automaticity of stimulus-driven effects is merely default in nature; this can be modulated or overridden by sufficiently strong endogenous attentional orienting (for example, when an anticipatory set is adopted for a specific spatial location; see also Ruz & Lupiáñez, 2002; for a review).

Moreover, this is particularly emphasized in Folk, Remington and Johnston's influential *contingent involuntary orienting hypothesis*, (1992) where they go so far as to suggest that top-down influences *always* play a role in attentional control. This hypothesis was tested via a letter detection task presented in a cueing paradigm, where the relationship between defining properties of the cue and task were manipulated. Across a number of different feature combinations (i.e. general or specific feature sharing, in respect of colour and onset), Folk and colleagues observed a pattern of performance costs on non-predictive cue trials (i.e. invalid trials), when cues and targets shared a unique feature.

On this basis, Folk et al., (1992) proposed that automatic, stimulus-driven attentional orienting mechanisms (i.e. such as attention capture by a specific feature) only operate when a concurrent attentional set (or mental template) has been adopted for that particular feature. Moreover, converging evidence from behavioural (e.g., Gibson & Amelio, 2000; Remington, Folk, & McLean, 2001; Pratt, Sekular, & McAuliffe, 2001) and neurophysiological investigations (e.g., Arnott, Pratt, Shore, & Alain, 2001) has lent additional support to the contingent involuntary orienting hypothesis. However, other work has suggested a level of flexibility in this control of attention, for example; the s*ingleton search strategy* (Bacon & Egeth, 1994) where a unique feature is actively sought by the observer, even though the nature of the property is not known (see also, Theeuwes & Burger, 1998; for further discussion on when top-down control can override attention capture).

2.2.8.3 *Inhibitory processes in endogenous attentional control*

Thus far, the focus has been on control processes that are facilitative in nature; that is, they *enable* relevant attentional processes rather than *hinder* their performance. Another facet of endogenous control of attention concerns those mechanisms which actively inhibit a particular action or process. These are equally important to effective performance in attention-based tasks (such as visual search) as, broadly speaking, they can act to prevent inefficient allocation of attentional resource. For example, these mechanisms can prevent the deployment of attention to locations or object-types that are irrelevant to a particular goal state (e.g., the operation of *inhibition of return* in visual search tasks; Klein, 1988). Two such mechanisms (*inhibition of return* and *negative priming*) are reviewed in the following section.

2.2.8.3.1 *Inhibition of Return*

Inhibition of return (or IOR) refers to an inhibitory mechanism that prevents locations, searched previously in task performance, from being returned to for subsequent re-search. Posner and Cohen (1984; see also Maylor & Hockey, 1985) demonstrated in the classical cueing task, that when a target was presented in a previously-cued location, within 300ms of the preceding cue, subsequent detection of the target was enhanced at that location. Conversely, when the target was presented after a 300ms delay, detection was impaired (i.e. presumably due to inhibition of the previously cued location). Posner and Cohen suggested that this was the result of a location-based mechanism, involving inhibition of previously searched locations (see also Klein & Taylor, 1994; Klein, 2000; for a review).

Later work by Tipper and colleagues (e.g., Tipper, Weaver, & Watson, 1996; Tipper, Driver, & Weaver, 1991; Tipper, Weaver, Jerreat, & Burak, 1994) has also revealed a more object-focused effect. In their 1991 study, Tipper and colleagues demonstrated that when a previously-searched object was moved, IOR would still be applied to that object, despite its relocation. In addition, Gibson and Egeth (1994) have shown IOR at a specific location of an object's surface, indicating that this mechanism can be effective when objects are rotated and in turn, that IOR can also be sensitive to surface properties of objects. However, the exact origins of the inhibitory mechanism are not yet held in consensus.

Theories exploring the origins of the IOR mechanism fall into three categories. Firstly, according to Posner & Cohen's account (1984; see also Posner et al., 1985), the IOR mechanism is attentionally-driven. That is to say, that the inhibitory effects are caused simply by the action of orienting attention to a specific location, and then explicitly orienting away from that location. Moreover, this viewpoint has been supported by evidence that apparently rules out simple sensory accounts of IOR (for example, by forward masking; e.g., Maylor, 1985; Posner & Cohen, 1984; Rafal, Calabresi, Brennan, & Sciolto,1989). However, according to Klein (2000), the involvement of the motor system was implicated in Posner and colleagues' early study (1985; but cf. Abrams & Dobkin, 1994).

In this instance, participants showed a tendency to make saccades away from a cued location (when given a free choice of eye movement to either the cued or alternative peripheral location), which Klein interpreted as a potential bias against making saccades towards the cue. Moreover, a number of studies have shown IOR effects firmly within the motor domain, using reaching tasks (Tanaka & Shimojo, 1996; Meegan & Tipper, 1998; Simone & Baylis, 1997; Tipper, Howard, & Jackson, 1997). Overall, Klein & Taylor advanced a motor bias stance, stating that "… IOR is a reluctance to respond to an event at the inhibited location (in other words, IOR, is more closely associated with responding than attention)." (1994; cited in Klein, 2000, p140).

Lastly, "hybrid" theoretical standpoints (e.g., Rafal et al., 1989; Pratt, Kingstone, & Khoe, 1997; Kingstone, & Pratt, 1999) have asserted that, whilst IOR is primarily an attentional phenomenon, occulomotor effects must also contribute to its operation. For example, Rafal et al., (1989) presented cues (at fixation or peripherally), to signal execution/ preparation of a saccade or covert shift of attention (without accompanying saccade). Delayed response to the target was demonstrated when the target had been presented at locations that observers had either just fixated, or planned to fixate, regardless of the location of cue presentation.

Whichever standpoint is adopted regarding the origins of IOR, the effects of the mechanism are clearer. Potentially reflecting a mechanism biased towards novelty (see Milliken & Tipper, 1998), IOR inhibits the re-orientation of gaze, covert attention and spatial response to locations or objects that have previously been searched or more generally, attended to. In turn, this allows the observer to make a more efficient search of the visual environment.

2.2.8.3.2 *Negative Priming*

This phenomenon has been extensively investigated by Tipper and colleagues in a number of domains (e.g., Allport, Tipper, & Chmiel, 1985; Tipper, 1985; Tipper & Cranston, 1985; Tipper, Lortie, & Baylis, 1992; Tipper, Brehaut, & Driver, 1990; Driver & Tipper, 1989; Tipper & Driver, 1988), and refers to a mechanism that acts to inhibit the impact of a particular stimulus, on the basis of its previous task-based "status" (see also Tipper 2001; Fox, 1995; May, Kane & Hasher, 1995; Neill, Valdes, &Terry, 1994; for detailed reviews). The typical negative priming task consists of two displays; a *prime display*, where the stimulus in question is presented as either distractor or target, followed by a *probe display*, where the stimulus' role is manipulated in congruence, opposition, or non-relation to the prime display (i.e. a stimulus could be presented in the same, different or unrelated "role"). Thus, trial types can take one of three forms; an *ignored repetition* trial, in which a stimulus presents a distractor in the prime display and a target in the subsequent probe phase; an *attended repetition* trial, when the stimulus is presented as a target in both phases; and lastly, a control trial, when components of the two displays are unrelated.

Tipper and colleagues (Allport et al., 1985; Tipper, 1985; Tipper & Cranston, 1985) presented participants with a task with spatially overlapping stimuli (i.e. letters or line drawings, usually in different colours), and asked them to detect the *red* item, for example, in both pime and probe displays. They demonstrated that, in attended repetition trials, performance was enhanced in comparison with control trials (when the arrays were unrelated). Conversely, they found selectively impaired performance when the stimulus status changed (i.e. the stimulus was presented as a distractor in the prime display, and a target in the probe phase), in comparison with the control. They accounted for this effect by proposing a mechanism that actively inhibits an unattended item, in order for the target to be subsequently selected. In this way, an impairment of unattended repetition trials would be demonstrated, given that an observer would have to select a target stimulus previously inhibited, due to its status as a distractor in the prime phase. In addition, the influence of top-down, anticipatory set-driven elements of this mechanism has been emphasized by a later investigation.

In this study, Tipper et al., (1994) illustrated the importance of goal states and task demands in the flexibility of this mechanism. Moreover, where the *defining* cognitive characteristics of a special population (i.e. either clinical or developmental) include decrements in suppression/ inhibitory function (e.g., young children, older adults, patients with mood disorders, or dementia), negative priming has been shown to be less robust (e.g., Tipper, Bourque, Anderson, & Brehaut, 1989; Hasher, Stoltzfus, Zacks, & Rypma, 1991; Tipper, 1991; Tipper & Baylis, 1987). This latter point is most relevant to propositions that negative priming may be attributable more to impact on perceptual processing, than inhibition per se (see Tipper 2001; Fox, 1995; for further details of competing accounts).

2.2.9 *Time-based selection in visual attention: The preview search task*

Thus far, the attentional mechanisms, paradigms and theoretical perspectives outlined have focused on a single mode of selection; that related to the spatial domain. However, a more recent attentional paradigm (*preview search*; Watson & Humphreys, 1997) has combined this spatial selection with a temporal element. Watson and Humphreys initially investigated a task that, at first glance, resembled the classic colour-form conjunction (e.g., Treisman & Gelade, 1980), with a blue H target presented amongst a blue A and green H distractor set.

The innovation in this task, however, comprised the presentation of the search array in two temporally distinct stages. In this instance, half of the distractor set (the green H distractors) was shown for 1000ms prior to the onset of the remainder of the distractor set (the blue A distractors) and the target, following which the full array would be searched (Experiment 1). This protocol allows designation of the half of the distractors as a *preview set*, with the distractors shown in the subsequent display defined as the *search set.*

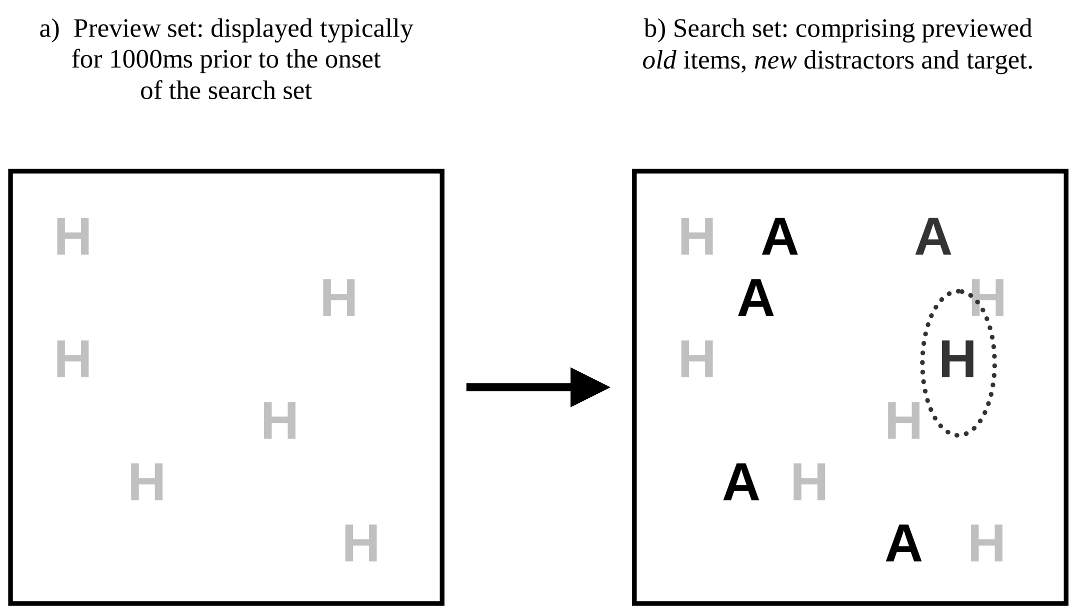


Figure 2.3 Example of a preview search task (Watson & Humphreys, 1997)

Under these circumstances, given the task's similarity to the classic Treisman & Gelade (1980) colour-form conjunction search, a relatively slow, serial search would be expected. However, in this instance, search performance was equivalent to that expected for a single feature search (e.g., the blue As and target H alone); indicating that the previewed items did not impact significantly on the subsequent search. Moreover, in order to examine these findings in the light of established theory, Watson and Humphreys conducted a number of further investigations into the source of this effect (also known as the *preview benefit*; Watson & Humphreys, 1997; 1998). Specifically, they examined the mechanisms underlying IOR, negative priming and attention capture by new items, to assess whether these could account for the search advantage gained by previewing a subset of distractors.

2.2.9.1 *Can the preview benefit by explained by inhibition of return?*

Recall that IOR acts so as to prevent a location (or object) previously searched, from being searched again after the elapse of approximately 300ms. As the preview duration (1000ms) in Watson and Humphreys' task exceeded that time window, it was possible that this mechanism could account for the preview benefit. To evaluate this possibility, Watson and Humphreys presented a task, similar to that described above, but where the previewed stimuli comprised degraded green H distractors (Experiment 4, see also Experiment 5 for an "offset" procedure). Following the standard 1000ms preview, these partial Hs were made complete, concurrently with the presentation of the search set and target.

According to an IOR account, this experimental design should have elicited a preview benefit, as the locations occupied by the previewed partial distractors should have been inhibited (*and* the preview duration was consistent with previous presentations). However, in this instance, no preview benefit was demonstrated, indicating that the locations of the previewed items were not inhibited; and thus IOR was unlikely to provide an adequate explanation. That said, Watson and Humphreys conducted an additional experiment (using box pre-cues) which further tested and ruled out IOR as an explanation for the preview benefit (1997; see Experiment 6).

In this case, Watson and Humphreys used a task more equivalent to the standard IOR paradigm (see Posner and Cohen, 1984). The preview set (again, green H distractors) was displayed for 750ms, followed by a brief offset (250ms), and their subsequent re-appearance at the same time as the search set and target (blue As and a blue H) were displayed. According to work evaluating IOR when an item displayed at an inhibited location subsequently disappears (e.g., Terry, Valdes, & Neill, 1994; see also Tipper, Weaver, & Houghton, 1994), this inhibition should not dissipate with the disappearance of the item. However again, no search advantage was demonstrated in these circumstances, suggesting that both old and new items were being searched, and IOR could not account for the preview benefit.

A more recent investigation of the potential impact of IOR mechanisms upon preview search (Olivers, Humphreys, Heinke, & Cooper, 2002; see also Kristjansson, 2000; Horowitz & Wolfe, 1998; 2001; Logan, Taylor, & Etherton, 1999; Treisman, Vieira, & Hayes, 1992, for discussion of the role *memory* plays in visual search), also supports the case for excluding IOR as a contributory factor. Here, Olivers and colleagues presented a *double search* preview task, comprising a display of heterogeneous letter stimuli (see also Theeuwes, Kramer, & Atchley, 1998; for a preview search task with similar stimuli). This *double search* entailed participants searching through a preview set for a target item (in contrast to the standard paradigm, when the preview set contains only distractor items). If no target was found, a subsequent display was presented (upon the participant's key-press response to the initial display), which would then be duly searched.

With this double search presentation, IOR would be expected for those locations (e.g., Kristjansson, 2000; Müller & von Mühlenen, 2000; Klein, 1988) searched serially during the initial search phase. In turn, this should elicit a strong search advantage for the subsequently-added items, since IOR should prevent the previously searched locations being revisited. However, Olivers et al., (2002) failed to demonstrate a clear preview benefit under these conditions, suggesting that IOR plays no role in generating this search advantage for new items. Taken as a whole, this evidence suggests that IOR cannot be held to account for the search advantage demonstrated with preview.

2.2.9.2 *Negative Priming and Preview Benefit: More explicatory power?*

Arguably, negative priming could be an alternative mechanism at work where preview benefit is demonstrated. Accordingly, Watson and Humphreys (1997) investigated this possibility by presenting a preview search that manipulated the number of preview set distractors (i.e. green H distractors) presented across both preview and search displays, whilst keeping the total number constant (Experiment 7). Thus, with a consistent total number of distractors (eight green Hs) shown; preview displays would contain 1, 4 or 7 items, and search displays would correspondingly comprise 7, 4 or 1 of this type distractors, together with the blue items (distractor As and a target H).

Here, if negative priming underpins the preview benefit, inhibition of the initially presented green Hs should impact on subsequent presentation of green H distractors, by spreading inhibition to those later representations. In effect, presentation of distractors in the preview display could be considered analogous to the prime display in the negative priming paradigm (with the full search display corresponds to the probe phase of the priming task). In terms of search performance, this should enable efficient search, since inhibited items would not be included in searching for the target.

However in this instance, Watson and Humphreys (1997) did not demonstrate a search advantage (i.e. corresponding to the inhibition of subsequently presented items). Instead, they found that RTs increased as the number of green Hs presented in the search display increased, which explicitly contradicts what would be predicted from the negative priming mechanism. This appears to rule out a negative priming account of the performance benefit accrued under the preview search paradigm.

2.2.9.3 *A feature map inhibition account*

One further potential account of the preview benefit involves an aspect of a visual search theory discussed above (i.e. Treisman & Gelade's FIT; 1980), but not in relation to inhibitory mechanisms. Watson and Humphreys (1997) argued that inhibition of a specific feature map (i.e. colour) might underlie the preview benefit, by the feature differences between target and preview set allowing inhibition of the distractor set feature map (i.e. without affecting coding of the target's features; see also Treisman, 1988; Treisman & Sato, 1990). In turn, this would mean that when any item shared a feature with the inhibited feature map, it could be effectively excluded from search of the full array.

However, when Watson and Humphreys (1997) investigated this possibility (Experiment 1; see Discussion section for additional detail), they found that, contrary to the predictions of a feature map inhibition account, items added to the display that shared the feature in question, were not excluded from subsequent search. As a result, search was impaired as these new items were added, which appears to preclude a feature map inhibition explanation of the preview benefit.

That is not to say that feature map inhibition should be excluded from a playing a role in the preview benefit. Subsequent investigations (i.e. Braithwaite, Humphreys, & Hodsoll, 2004; Braithwaite, Humphreys, & Hülleman, 2005; Braithwaite, Humphreys, & Watson, 2007; Watson & Humphreys, 2002; 2005; Watson, Humphreys, & Braithwaite, 2008) have explored the role of shared features between preview and search sets. If these studies are taken as a coherent body of work, they have examined, broadly speaking, two aspects of the impact of feature map processing.

Firstly, they have explored the impairment of inhibitory processes when a feature (typically colour) is associated with both the to-be ignored, old items and to-be-searched new items (*colour carry-over effects*). And secondly, they have examined how the use of this type of feature may be used to support the preview benefit mechanism's resistance to low-level, less behaviourally-relevant changes (i.e. local luminance changes; Watson et al., 2008; see also Rauschenberger; 2003; for further discussion of the impact of luminance changes). In summary, this indicates that colour (i.e. a specific feature) can play a role in this inhibitory mechanism in some circumstances.

2.2.9.4 *Is Preview Benefit a result of attention capture by new item onset?*

An alternative account of the preview benefit differs from those reviewed above by an important factor; these necessarily revolve around top-down, anticipatory set-based processing, whereas attentional capture by new items is arguably based wholly on bottom-up effects (but cf. Donk & Theeuwes, 2001, and see below). Given that the secondary (*search*) display in the preview search task comprises *new* items, in addition to those already previewed, this mechanism could potentially explain the preview benefit (e.g., Donk & Theeuwes, 2001,2003; and see Section 2.2.8.1, above). Initially, Watson and Humphreys (1997) investigated this possibility by presenting luminance decrements at the location of previewed distractors, concurrently with the onset of the new items (i.e. the search set and target; see Experiment 5).

According to Yantis and Johnson's (1990) work, establishing that luminance increments dominate luminance decrements, in terms of attention- this presentation should elicit a preview benefit (because the new items would be prioritized through the dominance of the luminance increments). However contrary to this account, a preview benefit was not shown in these circumstances; this indicates that new items were not prioritized over previewed ones, and that attentional capture by new items is not sufficient to induce a search advantage (see also Kunar, Humphreys, & Smith, 2003; for further discussion of this point).

2.2.9.5 *The contribution of top-down and bottom-up factors*

Above, there is some hint at the tension between accounts of preview benefit that rely on stimulus-driven mechanisms, and those that look to top-down factors to explain the effect. This debate will be discussed in more detail below, but there is evidence that the distinction is not entirely clear-cut. Alongside Watson and Humphreys' (1997) early investigation, which appears to preclude the contribution of attentional capture by new items, findings from Donk and Theeuwes (2001) explicitly contradict this. Whereas Watson and Humphreys found no preview benefit where new item onset would be expected to drive prioritization in subsequent search, conversely, Donk and Theeuwes found no preview benefit if new items were *not* accompanied by such luminance increment.

That said, other evidence points clearly to the impact of top-down influences. For example, Watson and Humphreys (1997) demonstrated that when processing is loaded during the preview phase of the task (e.g., via recitation of a number of rapidly presented digits on screen; see Experiment 8), preview benefit is accordingly disrupted. In turn, this suggests that the mechanism at work is subject to central capacity limitations (contrary to what would be expected from a bottom-up attentional process). This impact on capacity has been reflected in a variety of attentional paradigms conducted alongside preview search; for example, dual-task performance, within and across modalities (Humphreys, Watson & Joliecoeur; 2002); attentional blink (AB) tasks (Olivers & Humphreys, 2002). All of which evidence supports the notion that top-down influences play a role in preview benefit, since otherwise performance impairment in preview search would not be evident when attentional resources were depleted.

2.2.10 *How can Preview Benefit be explained? Three accounts*

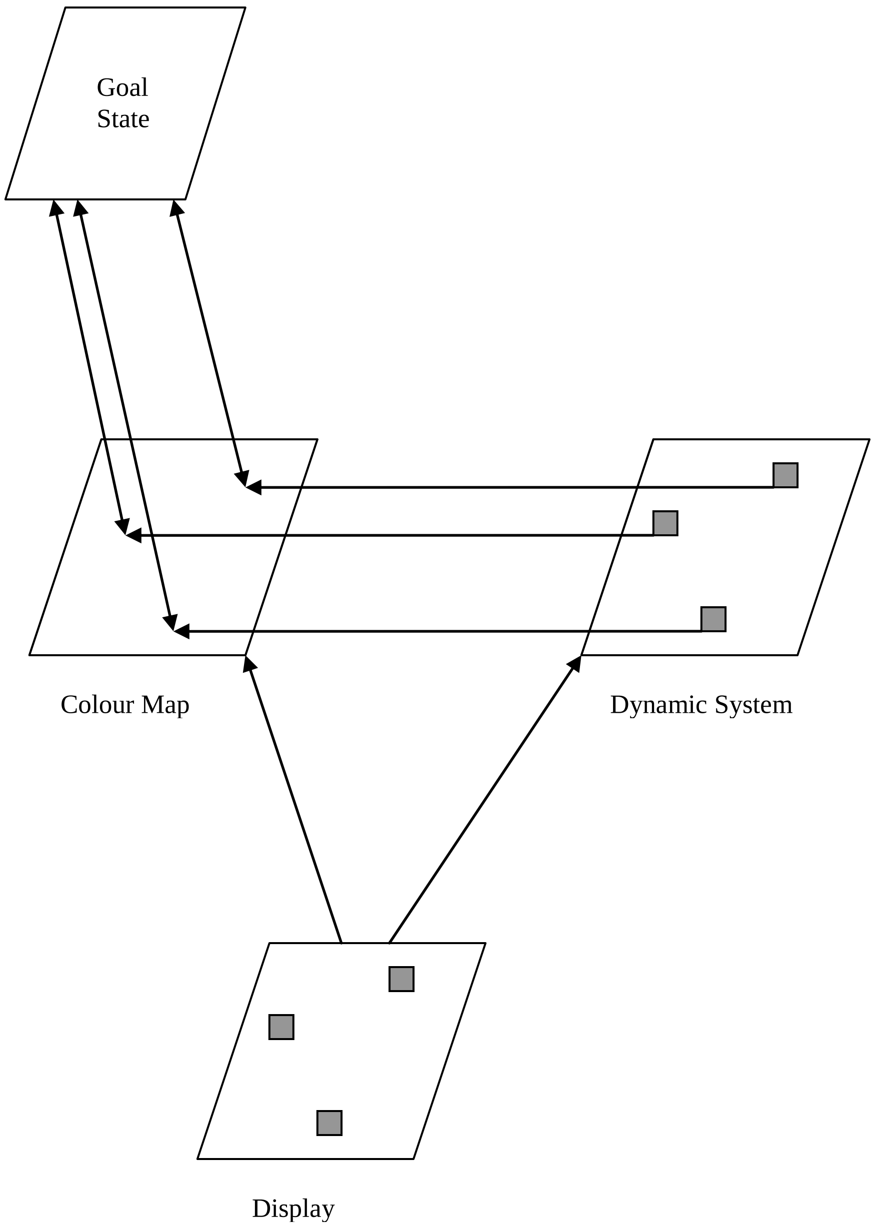
2.2.10.1.1 *Visual Marking*

Watson and Humphreys coined the term *visual marking* to describe the mechanism underlying the performance advantage demonstrated in preview search.

They summarized its component attributes thus: firstly, given evidence of resource-limitation concurrent with attentional loading (1997; Experiment 8), they asserted a top-down endogenous process that required attentional resource. Secondly, having excluded the contribution of other inhibitory mechanisms (such as negative priming, IOR or inhibition of feature maps, per se), Watson and Humphreys (1997) proposed that static stimuli must be *visually marked* via i) location-based inhibition, and that ii) inhibition must be applied to individual feature maps, in line with iii) the observer's (intention-driven) goal state (Experiments 4-7).

Evidence for this compound mechanism can be further adduced from work that decomposes these aspects. For example, dynamic changes at inhibited locations (e.g., the onsets and offsets presented in Experiment 4-5; Watson & Humphreys, 1997) appeared to disrupt the marking process sufficiently so as to override their inhibition (thus, abolishing any *preview benefit*). In addition, Watson & Humphreys' (2000) dot probe study emphasized the inhibitory nature of the mechanism; showing selectively impaired detection of a probe dot, when this was presented at the location of *old items,* compared with *new items.* Moreover, when Olivers & Humphreys (2002) investigated this inhibitory mechanism with use of the attentional blink phenomenon (AB), depletion of attentional resources (with the generation of the AB) led to weakened inhibition at the locations of old items. Lastly, the *intentional* (top-down) component of the *visual marking* mechanism has also been supported by subsequent work (e.g., Watson & Humphreys, 2000).

Figure 2.4 Watson and Humphreys' (1997) depiction of the *Visual Marking* mechanism, or *Top-down location-based inhibition mediated by a goal state*[4] (p117)



[4] Watson and Humphreys (1997) also state that "…Changes within the dynamic system at the location of a *visually-marked* stimulus modulates the template maintained by the goal state so that inhibition is removed from that location." (p117).

In this instance, when prioritization of new items was not task-relevant (i.e. there was no behavioural importance attached to inhibiting previewed stimuli), inhibition of probe dots presented at the locations of items was not demonstrated. Moreover, the mechanism has also demonstrated sensitivity to ecological considerations. For example, recent studies by Watson and colleagues (Watson & Humphreys, 2002, 2005; Watson, Humphreys, & Braithwaite, 2008) have demonstrated that changes to previewed stimuli only disrupt the preview benefit when those changes have behavioural significance (i.e. they present high-level shape or object identity changes, rather than low-level changes in luminance).

2.2.10.2 *Perceptual grouping by temporal asynchrony*

Jiang et al., (2002) suggest an alternative explanation for the preview benefit. Whilst they do not preclude the operation of an inhibitory mechanism outright, they propose that the search advantage is due to the ability to separate the old items (i.e. those in the preview set) from new items (i.e. in the search set) into two perceptually distinct groups. This, they believe, is facilitated by the temporal asynchrony of the two sets of stimuli, which enables attention to be applied to each group in turn.

The parameters of this proposed mechanism, and the resulting similarities/ differences between this account and that put forward by Watson and Humphreys (1997), have yet to be fully explored; however, it is possible to assert some similarity with a *visual marking* standpoint. It remains possible that the perceptual grouping mechanism, suggested by Jiang and colleagues, might operate on the basis of some perceptual bias or filter, similar to the inhibitory filtering proposed by Watson and Humphreys. In this way, the *perceptual grouping by temporal asynchrony* account of preview benefit might be regarded as an intermediate explanation, resting somewhere between the top-down, intention-driven mechanism proposed under *visual marking*, and the stimulus-driven *attention capture by new item onset* account, proposed by Donk and Theeuwes (2001).

2.2.10.3 *Attention capture by abrupt onsets: The New Item Onset account*

This account of the preview benefit lies diametrically opposed to that proposed under the auspices of the original work by Watson and Humphreys (1997). Whereas Watson and Humphreys excluded a purely attention capture based account (see Experiments 4-5), Donk and Theeuwes (2001, 2003) explicitly argue that abrupt onset of new items is necessary for the emergence of a performance advantage in preview search. Their original study (2001) manipulated the luminance of new items in the display against background luminance, and failed to elicit a preview benefit where new items were equiluminant to their background (Experiments 1 & 2). In fact, they only demonstrated a search advantage, when new items were presented with a simultaneous abrupt onset. This led to a strong assertion that prioritization of new items in a display is "…mediated by a mechanism…critically dependent on the detection of luminance changes." (Donk & Theeuwes, 2001, p 899).

However, that stance is mitigated somewhat by their acknowledgement that it is possible for bottom-up and top-down factors to play a role in the new item prioritization demonstrated in their study (i.e. participants had a temporal expectation for target presentation, inherent in their task). Moreover, subsequent work has shown that the circumstances in which Donk and Theeuwes (2001) suggested that no preview benefit could be demonstrated (i.e. where old and new stimuli were equiluminant with the background), does not hold when the typical preview duration is extended to take into account the difficulty of coding isoluminant stimuli (i.e. Braithwaite, Humphreys & Watson, 2006).

In summary, time-based attentional selection enables the observer to effectively discriminate between old (previewed items) and new items, conferring a performance advantage equivalent to search only through those new items in the display, and several accounts of this performance advantage have been proposed. However, although it is possible that a number of factors might play a role in time-based selection, currently the inhibitory *visual marking* mechanism (Watson & Humphreys, 1997) provides the most comprehensive and plausible account of the full range of data available in respect of preview search.

The debate between competing accounts of the preview benefit has clearly not been resolved completely, irrespective of which explanatory account is adopted. However, the relevance of the debate in respect of this thesis extends only so far as the attentional mechanisms that underlie the preview benefit interact with the properties of the emotionally-valenced facial stimuli used hereafter. In turn, prior examination of the attentional properties of emotionally valenced faces has been investigated predominantly through the visual search paradigm. The main themes and debates surrounding this relatively specialized literature will be explored in the next chapter.

Chapter 3:

Visual search with emotional faces

3 Visual search with emotional faces

3.1 Overview

Chapter 1 has reviewed a number of facets of face processing research, illustrating the impressive breadth of work in this area. Chapter 2 has addressed those aspects of the visual attention literature relevant to the empirical work to follow (i.e. visual search, selective attention, mechanisms of attentional control). However, this chapter brings together these two aspects, and considers the work most relevant to the remainder of this thesis. Thus, the focus here will be on the attentional properties attributable to the emotional face in its many representations, and exploration of these through the visual search paradigm.

It should be noted that several aspects of work in other attentional/ perceptual paradigms (e.g., flanker tasks; Fenske & Eastwood, 2003; Horstmann, Borgstedt, & Heumann, 2006; cueing tasks; Fox et al., 2001; Georgiou et al., 2005; perceptual load tasks; Lavie et al., 2003) *are* directly relevant to the empirical work that follows. However for the most part, findings from paradigms other than visual search will be discussed in relation to their relevance to specific experiments in later chapters. The chapter concludes with a brief overview of the empirical work comprising Chapters 4 to 7.

3.2 Early research into visual search with faces

Although there are a number of important papers documenting elements of face processing relevant to visual search prior to the 1980s (e.g., McKelvie, 1973; Yin, 1969), most researchers in this field would agree that this avenue of enquiry has sprung from a seminal paper over 20 years old. Hansen and Hansen (1988) first examined the effects of an emotionally-defined face singleton presented amongst a crowd of emotional face distractors, eliciting what they coined the *face in the crowd effect*, or *FICE*. This study utilized a search asymmetry methodology with photographic angry and happy faces from the Ekman & Friesen (1976) stimulus set, and demonstrated the attentional dominance of an angry face amongst happy faces, in comparison with the reverse configuration. Moreover, Hansen and Hansen went so far as to suggest that processing of the angry face was both automatic and preattentive (as shown by the highly efficient search); a claim that has been extensively explored over the ensuing years (e.g., Öhman, 2002; Öhman & Mineka, 2001; for extensive reviews, see Chapter 1 above; Frischen et al., 2008; Hortsmann, 2007; but cf. Wolfe & Horowitz, 2004).

However, other studies have explicitly cast doubt on this work. Purcell, Stewart and Skov (1996) identified a perceptual confound in the photographic stimuli used by Hansen and Hansen (1988), which they suggest may have led to the preferential processing of the angry face target. In turn, this has also prompted a vast raft of research examining the status of the emotional face within a visual search paradigm (i.e. Calvo & Nummenmaa, 2008; Calvo, Nummenmaa & Avero, 2008; Horstmann, 2007; Hortsmann & Bauland, 2006; Horstmann, Scharlau, & Ansorge, 2006, Schübo, Gendolla, Meinecke, & Abele, 2006; Eastwood et al., 2001; Williams et al., 2005;

Öhman et al., 2001; Fox et al., 2000; White, 1995; Nothdurft, 1993). Most often, this explored the role of the negatively valenced facial target, in terms of attentional guidance towards adaptively-relevant stimuli. Although these two research streams may seem functionally disparate, they have often run parallel in subsequent investigations; and have pervaded the *visual search with faces* literature to date.

3.3 The search advantage for threat faces

Following on from the early work of Hansen & Hansen (1988), the search advantage for negative faces has emerged as a dominant theme from the literature. With the exception of a few dissenting voices (e.g., Williams et al., 2005b; Juth, Lundqvist, Karlsson , & Öhman, 2005; see Section 3.3.3, below), a common finding has been for a negatively valenced face stimulus (i.e. displaying an angry, sad, fearful or "socially disapproving" expression) to be detected more rapidly amongst neutral or positively valenced distractors, than a positively valenced face is detected amongst negative or neutral faces (e.g., Eastwood et al., 2001; Öhman et al., 2001; Fox et al., 2000, Nothdurft, 1993; Horstmann & Bauland, 2006). In fact, it might be argued that this is the essence of the *visual search with faces* literature- or at least, lies at its heart. However, it should also be acknowledged that the experimental contexts for these findings have varied considerably (see Section 3.5).

With more consistency, the *nature* and *purpose* of this search advantage has been questioned, rather than the existence of the phenomenon itself. In turn, this has fed into the debate concerning the adaptive nature of threat processing, and how facial stimuli may be processed within a potentially hard-wired threat detection system (i.e. LeDoux, 1996, 1998; Öhman & Mineka, 2001). More generally, it can also be considered within a framework that asserts a negativity bias for multiple facets of human processing (e.g., Ito et al., 2002; Carretié, Mercado, Tapia, & Hinojosa, 2001).

3.3.1 *Threat detection and adaptive processing*

Preferential detection of any stimulus that indicates potential danger to the observer is a necessary function for ensuring that individual's survival. Accounts of biological preparedness (Seligman, 1970 1971) and adaptation to the selective evolutionary pressures of the early mammalian environment (i.e. Tooby & Cosmides, 1992) have led some researchers to propose a dedicated fear module that responds rapidly and automatically to a threatening stimulus (see Ohman & Mineka, 2001, for fear processing of animal stimuli, such as snakes or spiders). LeDoux (1996, 1998) has also famously examined the operation of a specialized fear processing mechanism from a neuroscience perspective.

The impact of an evolutionarily-adaptive threat detection mechanism has been considered in relation to affective stimuli, such as faces denoted by their negative valence (e.g., Mogg & Bradley, 1999; Ohman, 1999). However, this might be taken to indicate a schism in the literature. Whilst a negative face target search advantage has been well documented in the literature, some researchers have adopted a strong stance when defining which faces adequately convey threat (e.g., Öhman et al., 2001; and see below). Arguably, one could even assert that no face stimulus presented in controlled laboratory environment would ever present a realistic threat to an observer, irrespective of the neural circuitry lying in preparation.

Inevitably perhaps, this introduces another question to be considered in respect of facial stimuli. Is the reported negative face search advantage generalizable to every negative face (i.e. suggesting a broad negative/ positive distinction)? Or, should we consider those faces which indicate direct behavioural threat to the observer (i.e. angry or fearful faces) as a special case?

3.3.2 *The distinction between threatening and negatively valenced faces*

In their review of visual search with emotional faces, Frischen, Eastwood and Smilek (2008) state that, although negatively valenced faces are frequently detected more efficiently than positively valenced faces (e.g., Eastwood et al., 2001, 2005; Fox et al., 2000; Öhman et al., 2001), "… claims about the propensity of a *particular* emotional expression to attract attention are necessarily limited to the experimental set-up with which the detection advantage was obtained." (p 669). Most obviously, it is possible to emphasize this difference in respect of studies where a search advantage has been demonstrated for a threatening face (i.e. an angry face) but not for a face displaying a less arousing, negatively valenced face (i.e. a sad or fearful face; see Öhman et al., 2001; Fox et al., 2000). It is difficult, in these instances, to avoid the conclusion that some form of processing hierarchy exists for this type of stimulus.

Öhman et al., (2001) were explicit in their adoption of this stance. Following their finding of a search advantage for angry and scheming faces (but not for happy or sad ones), they proposed the term *threat superiority effect*, to reflect the dominance of threatening faces, in particular, rather than negative ones, in general. Williams and colleagues (2005b) found a similar performance advantage for angry faces, in contrast to sad or fearful stimuli (experiment 3), but arrived at a subtly different conclusion. They argued that, whereas angry faces evoke a direct threat to the observer (if laboratory-based experiments can be extrapolated to *real world* events), then a fearful face can be taken to denote threat elsewhere in the environment. Potentially, this would imply a more remote source of danger to the observer; and equally, this argument could apply to sad faces.

More generally, Williams et al., (2005b) have suggested that the search advantage observed with any given facial expression depends largely upon the search context in which the face is presented. For example, in their study, a performance advantage was shown for both angry *and* happy targets when their experiment comprised happy, angry, sad and fearful face targets. In addition, a study by Calvo et al., (2008) using six emotional expressions, showed that happy, disgusted and surprised facial targets were detected more quickly than sad, fearful or angry ones. This contradicts not only a generalized negative valence effect, but also the more adaptively-focused *threat superiority effect* (Öhman et al., 2001). Overall, this suggests a strong influence of the search context in which a facial target is presented, but also introduces an element of uncertainty into the literature.

Frischen et al., (2008) point out that it is highly unsatisfactory to propose a standpoint of "*it depends*" in these circumstances (p 669); particularly in a field such as visual attention research, when precision is strived for. However, they also draw attention to the fact that absolute claims in respect of a particular facial expression may be unwarranted. Context is always important in evaluation of an experimental methodology and subsequent findings. Perhaps then, a generalized stance that emotional facial expression can influence search performance is enough- from there, researchers can attempt to integrate their findings into a wider framework. Moreover, this may drive a stronger reliance on converging findings from neurophysiological studies, which could be taken to emphasize a broader adaptive relevance (i.e. rapid negative/ positive distinctions; Smith, Cacioppo, Larsen & Chartrand, 2003; or uncertainty/ ambiguity responses mediated subcortically; e.g., Whalen et al., 1998).

One last aspect that may impact on the influence of variations in experimental set-up (both target valence and search context) is individual difference attributable to the observer. Several researchers have investigated the effects of clinical and sub-clinical mood and anxiety disorders on detection of emotional faces in search (e.g., Fox, 2002; Fox, Russo, Bowles, & Dutton, 2001; and see; Georgiou et al., 2005; Mogg & Bradley, 1999 for examples in other attentional paradigms). A general finding of an enhanced search advantage for negative faces has been demonstrated where individuals display elevated levels of anxiety or social phobia (e.g., Kolassa, Musial & Miltner, 2007; Gilboa-Schechtman, Foa, & Amir, 1999). A generalized slowing of responses to positive faces has also been demonstrated with depressed participants (Suslow et al., 2001; 2004).

Attentional mechanisms have also been postulated to account for these effects. For example, Eysenck, Derakshan, Santos and Calvo (2007) suggest that anxiety constrains the influence of top-down processing, which may boost the impact of stimulus-driven effects. In a variation on the classical *zoom lens* analogy (i.e. Eriksen & Hoffman, 1973; Eriksen & Eriksen, 1974), some authors have also argued that arousal or stress can narrow the focus of attention (Hockey, 1970; Callaway & Thompson, 1953; Calloway & Dembo, 1950), to the extent that valuable information outside that attentional focus can be overlooked. Conversely, authors such as Derryberry and Tucker

(1994; see also Isen, Johnson, Mertz & Robinson, 1985; Isen & Daubman, 1984) suggest that positive affect can induce a dilation of attentional focus.

3.3.3 *Dissenting voices*

It is not difficult to find examples where visual attention appears to be deployed preferentially to positively valenced faces (e.g., Stone & Valentine; 2006, Kirita & Endo, 1995; Leppänen & Hietanen, 2004; Ekman, Friesen, & Ellsworth, 1982; Kirouc & Doré, 1983; Ladavas, Umiltà, & Ricci-Bitti, 1980) However for the most part, these instances can be distinguished from studies that display a search advantage for negative face targets on the basis of task or methodological differences. For example, a processing advantage for positive faces has been demonstrated where evaluation is made on the basis of very brief stimulus exposure (Stone & Valentine, 2006), or explicit expression recognition as opposed to detection (Kirita & Endo, 1995; Tenhunen, Leppänen, & Hietanen, 2003; Leppänen & Hietanen, 2004).

That is not to say that a search advantage is never demonstrated for positive faces. A number of studies have reported such effects (e.g., Juth et al., 2005; Williams et al., 2005b). Moreover, there are also studies where no preferential processing has been demonstrated for either negatively or positively valenced targets (see White, 1995). This leads us to two inter-related viewpoints. Firstly, it might suggest that a *general emotionality effect* (see Fox et al., 2000; Martin, Williams, & Clark, 1991) dominates search for emotional faces; that is, the emotional component of the face is more relevant than the valence or specific type of expression. This could account for those studies where no detection advantage is shown for either target valence, and in turn, points towards the importance of considering each study individually, before assimilating it into a theoretical framework that is not necessarily homogenous.

Moreover, this also supports Williams and colleagues' (2005b) emphasis on the influence of search context on detection of an emotional face target, *and* Frischen et al.'s (2008) suggestion that the attentional dominance of one emotional expression over another should not be asserted unequivocally. This focus leans more towards the question of whether emotional expression can guide attention in any event. And from that perspective, it is possible to evaluate the relative weight of evidence for the attentional properties, given the limitations of comparing across studies.

3.4 Are emotional faces processed preattentively?

Stemming from Hansen and Hansen's (1988) original claim, this question remains one of the most contentious, yet most fundamental, within the *visual search for faces* literature. For the most part, the question has been addressed through the parameters of the visual search task itself; by evaluating the "pop out" (See Section 2.2.5, above) of a given emotional face, or any relative search advantage for one target in comparison with another. This section will review the evidence provided by behavioural studies in the visual search paradigm; however, it will examine it from two perspectives. Frischen et al., (2008) have reviewed the evidence for preattentive processing of faces from evaluation of comparative search performance, whereas, Horstmann (2007) has explored it purely from a search asymmetry methodology. Note that these two perspectives may appear to overlap at times, and occasionally, discuss the same studies from opposing standpoints.

3.4.1 *Evidence from comparative search performance: Frischen's (2008) view*

An evaluation of comparative search efficiency might be conceptualized from literature contemporary with the early visual search with faces studies. Using Treisman and Gelade's (1980) distinction between parallel and serial search (and the target "pop out" phenomenon), Hansen and Hansen (1988) concluded that angry faces "popped-out" of their happy face distractor context, capturing attention automatically. Moreover, they asserted that the relative independence of RTs from increasing display size for angry face targets amongst happy distractors indicated a parallel search, which was thus, preattentive.

This strong assertion of the attentional properties of the negative face has been challenged on a number of levels. Firstly, Hampton et al., (1989) looked at the influence of position effects within the search array; which they reasoned should not impact search if processing of negative faces was truly automatic. Subsequently, they attributed the position effects they found for both negative and positive face targets to the effects of the valenced distractors (see Section 3.5.1.2, below), and countered the strong stance of Hansen and Hansen's work. However, White (1995) amongst others (see also; Eastwood et al. 2001; Frischen et al., 2008) cautioned against discounting the existence of attentional guidance effects, based on a finding of position effects alone.

Purcell and colleagues' (1996) work is well-known for its examination of confounds in the Hansen and Hansen (1988) study. However in addition, their work failed to demonstrate a negative face pop-out, when the stimuli were adjusted to account for the perceptual confounds in the angry faces (i.e. rendering the Ekman and Friesen, 1976; faces in greyscale). Equally, White (1995; see also Nothdurft, 1993) found no evidence of differential processing for negative face targets; although in this instance, both negative and positive schematic faces demonstrated a highly efficient search (with search slopes of 0 ms/item).

Whilst this appears to contradict the operation of preattentive processing of emotionally valenced faces, Frischen and colleagues (2008) have argued that this criterion is too strict. They argue that, similarly to basic feature singletons in a visual search array; pop-out is not a given (see for example, Yantis & Egeth, 1999). And thus, effective attentional guidance, driven by a particular stimulus, is not precluded by the absence of this strictly-defined phenomenon. They suggest instead, that the relative search efficiency of different search tasks can be used to evaluate whether preattentive processes are sensitive to the attentional properties of an emotionally valenced face.

Eastwood and colleagues (2001) were amongst the first to demonstrate this evaluative strategy (see p1004, for details of their rationale; and see Wolfe, 1994; Wolfe, Cave & Franzel, 1989; for additional detail). They found that a negatively valenced face was detected more efficiently than a positive face target (evidenced by a shallower search slope), with a distractor set that comprised neutral faces. Eastwood took this as evidence that the negative faces were processed preattentively, and were able to guide attention effectively to their location during search. A number of subsequent studies have adopted these parameters for performance evaluation, and have demonstrated comparable results with other negative face targets (e.g., Hahn et al., 2006; Hahn & Gronlund, 2007; Suslow et al., 2004; Suslow, Junghanns & Arolt, 2001; Suslow, Roestel, Ohrman & Arolt, 2003).

Öhman and colleagues (2001) utilized a similar design (i.e. with neutral distractor set) in two of their experiments (Experiments 1 and 2). These demonstrated an overall RT advantage for a negative face target, but failed to show any robust differences in search slopes. However, they attributed this to an artifact of the speed/accuracy trade-off demonstrated in the search for positive faces, and thus, concluded that the search for negative faces was, in fact, more efficient (see also Eastwood et al., 2005).

Despite the support for the sensitivity of preattentive processes to emotional faces, evidenced by comparative search performance, one distinctive exception remains. Horstmann et al., (2006) failed to demonstrate any search efficiency differences between negative and positive targets presented amongst neutral distractors. In this case however, there is one potential source of discrepancy. Whereas previous studies had used a characteristic "straight line" mouth to indicate emotional neutrality, Horstmann et al., (2006) superimposed upwards and downwards curves to provide a "neutral" expression. The "straight line" mouth might be seen as questionable as to its emotional neutrality (see Chapter 8, below), certainly when considered context-free of a valenced target (see also Becker, 2009; Neth & Martinez, 2009). However, the neutral face selected by Horstmann et al., (2006) is arguably more negative than any other negative schematic face used in similar studies. Thus, it is difficult to reconcile this study with the rest of the literature examined in Frischen et al.'s review (2008), despite its importance.

3.4.2 *Evidence from search asymmetries: Hortsmann's (2007) view*

In his review, Horstmann (2007) examined the claim for preattentive processing by focusing predominantly on those studies that have utilized a search asymmetry design (see Section 2.2.6 above), given its suggested diagnostic status for establishing preattentively available features (i.e. Treisman & Souther, 1985; Tresiman & Gormican, 1988, but see also Wolfe & Horowitz, 2004). Despite the departure from photographic stimuli, following the controversy surrounding Hansen and Hansen's (1988) original stimuli, Horstmann reported that no classically defined search asymmetries had been demonstrated in visual search studies using more tightly controlled facial schematics (i.e. White, 1995; Nothdurft, 1993; Fox et al., 2000; Öhman et al., 2001 Horstmann, Scharlau and Ansorge, 2007; but see Horstmann & Bauland, 2006; for a negative face search asymmetry[5] with photographic faces). That said, he highlighted the fact that the majority of these studies had demonstrated either an efficient search for negatively valenced face targets (e.g., White, 1995; Horstmann et al., 2007) or a relative search advantage for those negatively valenced targets (e.g., Fox et al., 2000; Öhman et al, 2001), demonstrated via an overall RT advantage. Thus, this appears to speak more directly to Frischen et al.'s (2008) theoretical standpoint on how preattentive processing should be evaluated.

From Horstmann's perspective this appears, prima facie, to negate preattentive processing of negative faces in visual search. However, Horstmann (2007) drew attention to one important factor that requires consideration. Reasoning that the disparity of experimental design and stimuli adopted may have contributed to the absence of strong evidence in support of preattentive processing, he standardized the methodology of a number of these studies (but maintained their previous stimuli), and then, replicated them to provide a more systematic evaluation.

[5] Note that the authors referred to this finding as a *search inequality*, as their effect did not meet the traditional requirements for a search asymmetry (e.g., Treisman & Souther, 1985).

Under these circumstances, he drew the following conclusions; i) that evidence for preattentive processing of negatively valenced faces is only weak “at best” (Horstmann, 2007; p 822), ii) a *search inequality*, not complying with the traditional parameters of a search asymmetry, but showing similar trends, was demonstrated throughout, although iii) this was demonstrated to differing degrees, varying with the stimuli utilized. Moreover, Horstmann observed considerable differences between search slopes, according to the particular stimuli- *and* that did not necessarily correspond to findings in their originating study. Lastly, he was able to exclude confounds due experimental design as a source of the variability of findings. That is, a classical search asymmetry was seen in one experiment (Experiment 1) but not the others, showing the procedure itself was not precluding its demonstration.

In summary, the disparity between Horstmann’s approach and that of Frischen and colleagues might appear irreconciliable at first glance; however, that does not mean conclusions cannot be drawn across the two reviews. If preattentive processing (and corresponding attentional guidance) are judged only on the basis of strict criteria, derived from visual search methodology (i.e. search asymmetry or target “pop out”), then claims pertaining to the attentional properties of emotional faces appear weak. Both Horstmann (2007) and Frischen et al., (2008) concede this point. However, if a more flexible, contextually-grounded approach is taken (i.e. following Eastwood et al.’s rationale; 2001), it is clear that the deployment of visual attention demonstrates some form of preferential processing to the emotional face.

That said, further work is needed to reach solid conclusions; especially if we accept Frischen and colleagues’ suggestion that it “…makes little sense to argue over which specific emotional expression is guides attention better than another given strong evidence that visual search is a highly contextualized and dynamic process." (2008, p669). It is possible that paradigms that attempt to disentangle pre- and post- attentive mechanisms (i.e. Smilek et al., 2007), or examine attentional effects through more direct behavioural measures, such as eye movements (see Calvo et al., 2008; Reynolds et al., 2008) may provide evidence that is flexible enough to counter Frischen et al.'s argument (2008).

3.5 Can we consider the *visual search with faces* research as a coherent whole?

Notwithstanding the validity (or otherwise) of the claims made in the original Hansen and Hansen paper (1988) and the strength of evidence supporting a search advantage for negative faces, one aspect of the literature is apparent to even the casual observer; its heterogeneity. This observation has been made number of times within the literature itself (e.g., Horstmann, 2009; Frischen et al., 2008; Hortsmann, 2007; Williams et al., 2005b; see also Lipp et al., 2009; for similar comment in respect of visual search with inverted faces). However, it is possible that these differences may not be as problematic as these commentators might indicate. This section will briefly assess distinctions that can be made on these two counts and evaluate the degree to which they might impact on the overall theoretical standpoint.

3.5.1 *Methodological inconsistencies in the literature*

3.5.1.1 *Set size variation*

In order to draw confident conclusions about the search efficiency of a given data set via its search slope, it is generally held (see Frischen et al., 2008, for a review) that at least three display sizes should be presented to evaluate whether the RT data fits sufficiently well to a linear function. Furthermore, Frischen and colleagues assert that a design utilizing two display sizes does not necessarily preclude a representative evaluation of the data, but does not allow deviation from a linear trend[6] to be adequately reflected or assessed. This can be seen as somewhat problematic in light of the literature as a whole.

A number of studies examining visual search have chosen not to vary the set size of their search task (Schübo et al., 2006; Tipples et al., 2002; Byrne & Eysenck, 1995; Hansen & Hansen, 1988; Experiment 1 and 2; Öhman et al., 2001; Experiments 1 and 4; Fox et al., 2000; Experiments 1- 4), whilst others, (e.g., Hansen & Hansen, 1988; Experiment 3; Fox et al., 2000; Experiment 5) have presented a task with two variations in the set size. The latter case is obviously limiting for the reasons outlined above, however, in the case of the former, the informative value of the data is largely constrained. For example, in Hansen & Hansen's (1988) original two experiments, they presented "crowds" of identical size, varying only the mapping of target and distractor emotional valence (i.e. angry versus happy, and vice versa).

In this instance, whilst it was possible to evaluate performance on the basis of RT performance (i.e. that angry faces were detected more rapidly), this design meant it was not possible to infer any part of the attentional mechanism underlying performance differences, or to differentiate other aspects of task performance that may have been affected by stimulus valence (i.e. encoding or response selection). Hansen and Hansen went on to vary their set sizes between four and nine items in subsequent experiments in

[6] Frischen et al. (2008) make the point that a quadratic trend might explain nearly all of the variance demonstrated in a two set-size dataset, but would be very difficult to interpret in terms of attentional guidance.

their study, to circumvent this experimental constraint. In turn, this allowed their initial claim of preattentive processing (on the basis of both a search asymmetry *and* efficient search for a negative face target) to inspire further investigation. Overall, the methodological inconsistency this introduces makes systematic review of the literature difficult.

3.5.1.2 *Target- Distractor mapping*

In this respect, investigation of visual search has fallen largely into two camps. Several studies have examined the effects of an emotionally valenced facial target in a distractor set that is held constant across trials, blocks or experiments (e.g., Eastwood et al., 2001; Öhman et al., 2001; Experiment 2;). This would mean that a target of whatever emotional expression is consistently presented within an emotionally neutral distractor context, allowing direct comparison of search performance between the two target presentations (e.g., Smilek, Eastwood, & Merikle, 2000; Eastwood et al., 2001)

However, studies have also frequently utilized a search asymmetry-style design (e.g., Horstmann, 2007; Horstmann et al., 2006; Hansen & Hansen, 1988; Öhman et al., 2001; Experiment 3; Fox et al., Experiment 5; White, 1995; Experiment 1; Nothdurft, 1993; Study 5), where a particular stimulus adopts the role of target in one search task, and distractor in another. Whilst this may speak to the potential preattentive processing of a particular feature (i.e. Treisman & Souther, 1985, Treisman & Gormican, 1998; and see comments on Horstmann, 2007; below), it is less useful in determining the attentional guidance attributable to each specific target. This is due to the confounding effects of presenting emotionally valenced faces as both distractor set and target; it is impossible to disentangle detection of the target (from which attentional guidance to the target can be inferred) from dwell time on the distractors (which may speak to differential disengagement according to stimulus valence; see Fox et al., 2001, 2002; Georgiou et al., 2005). This seems particularly likely, given that search performance is generally more efficient when distractor sets are neutral than when they are emotionally valenced (i.e. Lundqvist & Ohman, 2005; Ohman et al., 2001; White, 1995; Byrne & Eysenck, 1995) Moreover, variable distractor- target mapping may distort understanding of visual search with faces in other ways. For example, on trials when no target is presented, search through negative distractor sets is often shown to be slower (e.g., Fox et al., 2000; Hansen and Hansen, 1988; White, 1995). This could be due to mechanisms facilitating efficient rejection of positively valenced distractor sets (Horstmann, Scharlau & Ansorge, 2006), more “fluent” processing of positive faces (i.e. Lepännen et al., 2003), or difficulties in disengaging from negative stimuli, per se (see Fox et al., 2002).

Furthermore, the finding that a unique emotional face presented amongst an emotionally valenced distractor set demonstrated more effective target detection when that distractor set was positively valenced (rather than negatively valenced; see Horstmann et al., 2006) has been extended by subsequent work. Hahn, Carlson, Singer and Gronlund (2006) have also evaluated the effects of valenced distractors presented with neutral targets. In this case, they found that search efficiency in trials with negatively valenced stimulus sets was markedly impaired, in comparison with trials when positive or neutral distractor sets were used.

In summary, this appears to present incontrovertible evidence of the importance of maintaining consistency within target-distractor mapping. In fact, Frischen et al., (2008) go so far as to stipulate two further conditions in order to prevent potential confounding effects of distractor and target valence; suggesting that i) distractor stimuli need to be affectively neutral, and ii) these stimuli need to be perceptually equivalent to targets. However, they also acknowledge that embedding emotionally valenced targets in emotionally valenced distractor sets can also be valuable in determining the relative contribution of attentional biases to targets and distractors respectively. Thus, it is possible that this particular variation in methodology hinges upon the purposes for which the investigation is designed; one design is appropriate for evaluation of attentional guidance, another for the diagnostic purposes of search asymmetry.

3.5.1.3 *Prior knowledge of target identity: Contrast of top-down and bottom-up influences*

Established visual search theory has accepted that search performance can be modulated by top-down influences (e.g., observer strategy; Smilek, Enns, Eastwood, & Merikle, 2006; or task demands; Theeuwes, 1990). However, for the most part visual search tasks using facial stimuli have relied on stimulus-driven search mechanisms, by presenting a single discrepant face target amongst facial distractors (in other words, an odd-one-out style search task). In contrast, Williams et al., (2005b) also examined the effects of participants having prior knowledge of target identity.

When Williams and colleagues evaluated search performance in both of these task formats, happy and angry faces were detected more rapidly than sad or fearful ones, when target identity was unknown. However, when observers knew which target face to detect (i.e. participants could adopt a specific search goal), search performance was enhanced for happy and angry faces, but did not affect sad or fearful facial targets. This has been interpreted (see Frischen et al., 2008) as indicating that observers can adopt flexible search strategies according to the facial expression of a target, but also suggests that task demands per se may impact on those search strategies.

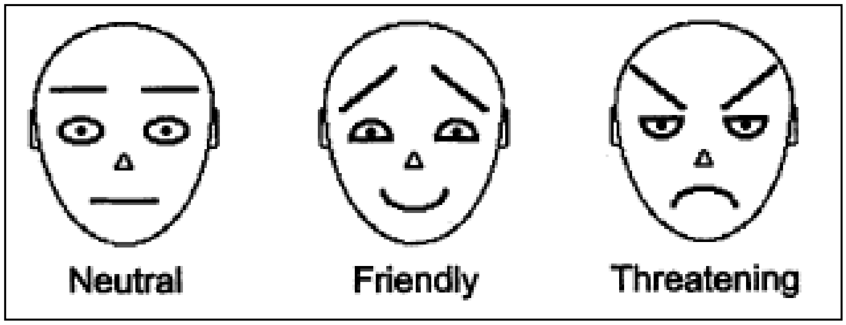
In addition, Hahn and colleagues (2006, 2007) have investigated the influence of top-down awareness of target identity. In the first instance (Hahn et al., 2006), the task required an observer to report the presence or absence of a given facial expression in a distractor set of neutral faces. On trials where the target was present, the facial expression could either be goal –congruent (i.e. consistent with the observer's to-be-reported face) or goal- incongruent. On congruent trials, search rates were enhanced for negatively valenced faces in comparison with positive faces. However, on incongruent trials, despite an overall slowing of RTs, a negative *goal* face (but positive *search* face) elicited increased search efficiency in comparison with the reverse configuration. Conversely, in a similar experimental design, Hahn and Gronlund (2007) observed equivalent search slopes in trials with a goal-incongruent face. This was attributed to the joint role of bottom-up (i.e. emotional face) and top-down (i.e. observer strategy) attentional guidance; with the latter particularly influential in search performance.

Evaluating the impact of top-down influences may be clearer when task demands are dissociated from the effects of direct attentional guidance. Horstmann & Becker (2008) used a task that required participants to detect a target feature (e.g., a specified colour conjunction, or a facial feature of a particular shape) within a group of faces containing a schematic emotional singleton. On valid-cue trials, the unique face contained the searched-for feature, with invalid-cue trials placing the feature on one of the distractor faces. Although overall, valid-cue trials elicited more efficient search performance than invalidly cued ones, no differential effects on the basis of facial valence were demonstrated (i.e. there were no consistent search differences for negative or positive cues amongst neutral distractors, but, cf. Horstmann et al., 2006). Overall, this highlights the impact of emotional faces, even when they are not directly relevant to task performance. However, similarly to other examples of stimulus-driven attentional phenomena (e.g., attention capture), it appears that these effects can be overridden, given sufficiently strong top-down influences (see also, Williams et al, 2005b.)

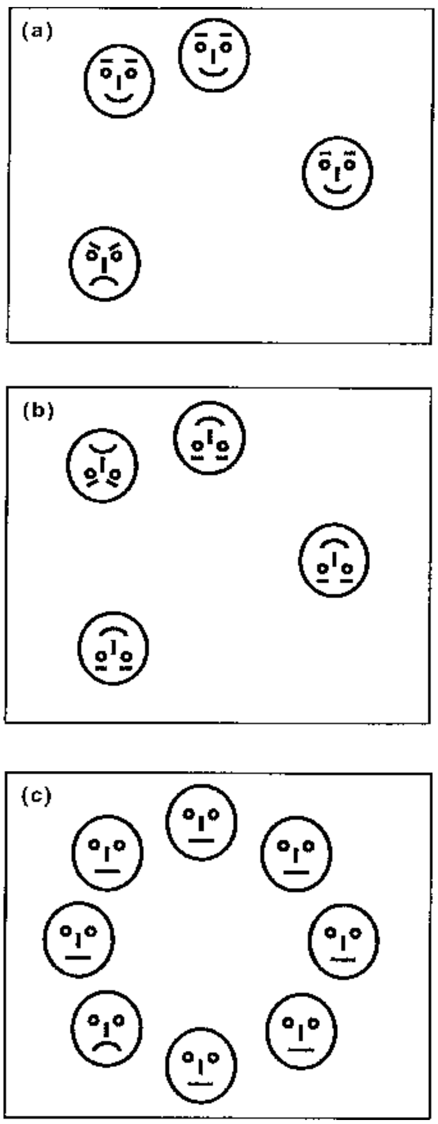
3.5.1.4 *Disparity in facial stimuli*

In terms of the facial stimuli selected for use in visual search, studies fall into two broad sub-divisions. Some studies have retained more ecologically valid photographic facial representations (e.g., Hampton et al., 1989, Williams et al., 2005b; Hershler & Hochstein, 2005; van Rullen, 2006; Horstmann & Bauland, 2006) emphasizing the importance of realistic facial representations and subtle variation in expression. These studies have frequently adopted the stance that facial stimuli, other than photographs, are *relatively impoverished* (Calder et al., 1996). Others have opted for simpler schematic stimuli (see Hortsmann, 2007; Lipp et al., 2009; Fox et al., 2000; Eastwood et al., 2001; 2005; Öhman et al., 2001; White,1995; Northdurft, 1993), whereby variability of perceptual salience, individual difference in photographic pose and spatial configuration of features can be tightly controlled. That said, differences between facial schematics can also be considerable (note the difference between Ohman et al.'s (2001) complex line drawings and Eastwood and colleagues (2001) straightforward "smileys", see Figure 3.1 below).

Figure 3.1 Examples of schematic facial stimuli

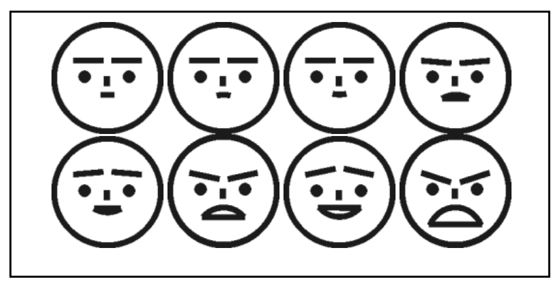


Öhman, Lundqvist, and Esteves (2001)

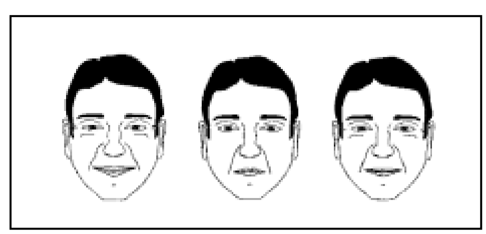


Fox et al., (2000)

Eastwood, Smilek, & Merikle (2001)



Hortsmann & Ansorge (2009)



Musterle & Rössler (1986)

However, Horstmann and Bauland (2006) have contended that the subsequent bias towards schematic representations was an overreaction to the perceptual inconsistencies between photographic stimuli. They suggested that such perceptual confounds between faces were not related to the differences in expression, and that artifactual findings are easy to identify on this basis. Furthermore, more general behavioural and neurophysiological data suggest that differences between schematic representations themselves, and between photographic and schematic faces are less striking (and less relevant) than one might think.

Given that line drawings, schematics and photographs of faces have been shown to elicit similar electrophysiological response (see Sagiv & Bentin, 2001; Wright et al., 2002) that mirrors the processing flexibility demonstrated by face- specific cortical areas (e.g., Kanwisher et al., 1997), it may be possible that facial stimuli are broadly equivalent in terms of visual processing. On the one hand, it might be argued that schematics are stereotyped and contrived in comparison with more naturalistic stimuli, and introduce perceptual confounds not present in photographs (i.e. the perceptual congruence of the smiling curved mouth and the facial outline in a positive face; see Purcell & Stewart, 2006; see also Wally & Weiden, 1973; for an outline of the *lateral inhibition* account). However, it has also been noted that the posed facial expressions depicted in typical photographic faces are equally artificial, and thus potentially, equally unrepresentative of a realistic representation (see Russell, 1994; p130, for a detailed discussion of this point).

In this way, it might be argued that stimulus selection is more a matter of choice and/or task appropriateness. Facial schematics are accepted as being particularly suitable for conditions where experimental control is paramount (e.g., visual search and other attention-based paradigms), and have also been shown to effectively convey emotional content that is easily recognizable by observers (see McKelvie, 1973; Magnussen, Sunde & Dyrnes, 1994, respectively). Conversely, photographs enable a wider range of nuanced facial affect to be displayed (notwithstanding the fact that most photographic sets tend to adhere to displays of basic emotions; e.g., Ekman & Friesen, 1976; Tottenham et al., 2002). Perhaps then, the wrong questions are being asked in this respect; a more relevant question should consider facial representations as a whole and ask- what properties of the emotional face influence deployment of attention?

3.5.2 *Sources of the attentional properties of the emotional face*

Differences between the emotional faces used in the studies described above beg the following question; if these facial representations differ, is it possible to distinguish what perceptual features, emotional characteristics or facial attributes elicit the attentional effects characteristic of search for negative faces?

3.5.2.1 *Perceptual properties*

Purcell and colleagues (1996) drew attention to the non-emotional properties of the emotional face in their critique of Hansen and Hansen's original study (1988). Their perceptual analysis of the stimuli used suggested that salient dark patches on angry face stimuli had biased search. In fact, in their subsequent replication, they ascertained that search performance was enhanced for observers that overtly used these contrast cues, and for faces where these cues were most salient.

Calvo and Nummenmaa (2008) addressed this issue directly, by investigating the role of perceptual salience in visual search for emotional faces. Their study examined detection of an emotionally discrepant photographic face (comparing six different emotions), amongst neutral distractor faces; but in addition, they analysed performance in conjunction with a computationally-modelled saliency map. Here, they established that saliency was most prominent for faces (and *parts* of faces) that were fixated earlier and detected faster. Moreover, Calvo and Nummenmaa asserted that the interaction of low-level visual processing versus the higher level configural mechanisms, characteristic of face processing (see Chapter 1, above) may hinge upon how consistent perceptual representations are in these two processing streams. For example, the relative contribution of these mechanisms may depend upon instances where a perceptually salient feature coincides with a semantically salient exemplar of a particular emotion (for example, a smiling mouth)

Attempts to avoid these potential perceptual confounds lead back into the photographic/schematic dichotomy outlined above. Without restating the arguments set out there, it is clear that this debate will not be settled easily. Moreover, it is equally clear that this is not an aspect of this type of research that can be overlooked or dismissed lightly.

3.5.2.2 *The emotional content of face stimuli*

The influence of the affective properties of facial stimuli is usually evaluated by exclusion; that is, by inverting the facial stimuli in question. The rationale runs that, if the perceptual features are kept constant and processing of the emotional content of the face (and characteristic holistic facial processing; Tanaka & Farah, 1993; McKelvie;

1995; Yin, 1969; see Lipp et al., 2009; Valentine, 1988; for reviews) is disrupted by inversion, then performance differences properly attributable to affective content should dissipate.

A number of studies have advocated this approach (see for example, Ashwin, Wheelwright, & Baron-Cohen, 2006; Fox & Damjanovic, 2006; Fox et al., 2000; Williams et al., 2005b; Eastwood et al., 2001; Öhman et al., 2001). However, some of these studies have demonstrated equivocal findings, and a recent evaluation of the effect has cast serious doubt on its value in this respect (see Lipp et al., 2009). Moreover, there is evidence that face inversion does not preclude the extraction of facial affect (e.g., Lipp et al., 2009; Eastwood et al., 2001). A more detailed review of this topic can be seen in Chapter 4 below.

However, an innovative method of evaluating stimuli in this way involves overlaying affective meaning on ostensibly valence-neutral and perceptually identical stimuli (see Batty, Cave & Pauli, 2005). Gerritsen et al., (2008) employed a number of affectively-neutral photographic faces, to which participants had previously been conditioned to attribute “peaceful” or “hostile” labels. Search involved a target face that was differentiated by identity only from the distractor set. Although effect sizes remained small, a persistent search advantage was displayed for those targets previously designated as “hostile”. The authors argue that the magnitude of the effect may be due to a relatively weak association of emotional valence with inherently neutral facial stimuli. However, this does suggest that emotional meaning is a factor that should not be overlooked when evaluating faces that *do* convey affective information.

3.5.2.3 *Elements of face, "characteristic" of facial affect*

Some authors have made strong claims regarding aspects of facial stimuli that dominate facial affect processing; for example, V-shaped eyebrows conveying threat (e.g., Tipples et al., 2002; Öhman et al., 2001; Aronoff, Woike, & Hymen, 1992), or specific facial regions such as mouths or eyes (see Fox & Damjanovic, 2006; Horstmann & Bauland, 2006; Whalen et al., 2004; Morris, DeBonis, & Dolan, 2002). This point, levelled more frequently at facial schematics (e.g., Purcell & Stewart, 2006), has also been extended to abstract stimuli that simply mimic the shape of this feature (i.e. Larsen, Aronoff, & Stearns, 2007). If we accept that this is the case, it remains difficult to establish whether this is attributable to affective or perceptual properties, or indeed, global or local processing of that face stimulus.

Öhman et al., (2001) examined this facet of their schematic stimuli by manipulating individual components of the face as well as their configural relationship. They used stimuli that represented five facial expressions (i.e. friendly, threatening, scheming, sad or neutral), in which the eyebrow, mouth and eye features differed only in orientation across different facial schematics. When presented amongst neutral *and* emotional distractor sets (Experiments 1, 3, 4 and 5), the threatening face target attracted most effective search performance. More importantly, this indicated that a holistic representation of the face was important, over and above the individual influence of individual features (as the threatening and sad faces shared identical eyebrows and mouth shapes, and neither feature could account for the differences in search performance).

Tipples et al., (2002) focused particularly on the effects of the eyebrow feature, using stimuli very similar to those used in Ohman et al.'s work (2001). In this instance, scheming and threatening faces were detected more rapidly than either sad or happy faces. However, when analyses focused on mouth and eyebrow components alone, they found that faces displaying the characteristic threatening “V” eyebrows were detected preferentially to those with inverted “V”s, although search performance was equivalent across expressions.

Interestingly, when threat eyebrows were placed out of facial context (i.e. separately, or above non-facial schematics), no effects of differential processing were demonstrated. Modulation of search performance by the “faceness” of a given schematic was also supported by later work (Lundqvist & Ohman, 2005; Schübo et al., 2006, but cf. Larsen et al., 2007), who found no influence of either individual facial components or configuration, when a non-face stimulus was used. Moreover, when ratings of threat had been also been taken (i.e. Tipples et al., 2002; Öhman & Lundqvist, 2005), it appeared that perceived threat modulated search performance; the more threatening a face was rated, the faster it was detected in search.

In studies using photographic stimuli, researchers have focused on both the eye and mouth region, with conflicting results. When Fox and Damjanovic (2006) examined emotional faces with either mouths or eyes visible, they found that angry faces were detected faster, but only when the eye region was presented. When mouths were presented in isolation, no performance differences were demonstrated. This finding is in line with a number of other studies pointing towards the importance of eyes in the processing of facial affect (e.g., Adams et al., 2003; Morris et al., 2002; Whalen et al.,

2004) and has led the authors to assert a privileged status for certain facial features in conveying threat.

However, Fox and Damjanovic (2006) have also indicated that the specificity of the effect seen with their stimuli should not be generalized to all facial stimuli; other facial features may be equally important in terms of conveying facial threat or affect in general. Horstmann and Bauland (2006) concurred with this viewpoint, but from a different theoretical perspective. Following from findings that emphasized the importance of the mouth region, rather than the eyes, for negative face search advantage, they argued that an attentional bias to any particular facial feature did not necessarily pertain to the affective content emotional expression itself. Rather, they argue, facial expressions may have evolved to take advantage of pre-existing attentional biases to certain facial features.

In all, there is evidence to suggest that each of these factors (i.e. perceptual salience, emotional content and specific facial features) can all play a role in the attentional biases attributed to the emotional face. It is also commonsense that, when of these factors dominates the other (e.g., the dark patches in Hansen & Hansen's (1988) faces or Tipples et al's (2002) salient eyebrows), the dynamic interaction of these factors will be shifted and performance may be affected. However, it is very difficult to ascertain the contribution of each without an experimental design that specifically attempts to examine that facet of the stimulus. Thus, the evidence that these factors adopt particular relevance only when presented in a facial context (but, cf Larsen et al., 2007), is reassuring in that the concord of these three aspects appear to form a gestalt representation to which the visual system responds.

3.6 Overview of the remaining chapters of this thesis

The remainder of this thesis is divided into five chapters; the first four (Chapters 4-7) dealing with experimental work, and the final chapter (Chapter 8) serving as a review and discussion of the findings, particularly in respect of current theory and the impact they may have upon future investigation. Chapter 4 presents preliminary work, which aims to evaluate the schematic faces selected in terms of their suitability for use in visual search tasks. Chapters 5, 6, and 7 comprise the main body of the present empirical research, and explore various aspects of preview search with emotionally valenced facial schematics as stimuli. This synopsis is expanded below.

3.6.1 *Chapter 4: Visual search with emotionally valenced schematic faces: Does contrast polarity make a difference?*

This chapter is designed to provide an evaluation of the stimuli and search displays that will be used throughout the remainder of this thesis. The chapter comprises two experiments; the overarching aim being to determine whether these facial schematics elicit effects in line with similar stimuli (i.e. those in previous studies examining visual search with faces, see above). These experiments also assess whether the contrast polarity of the search display systematically affects search performance- whether this is performance in general, or specifically, according to emotional valence. Lastly, search performance is examined when facial stimuli are presented in upright and inverted orientation.

3.6.2 *Chapter 5: Emotionally valenced schematic faces in preview search*

Chapter 5 investigates the operation of emotionally valenced facial schematics within the preview search paradigm (Watson & Humphreys, 1997) and comprises five experiments. Given the weight of evidence suggesting that faces, and particularly emotional faces, attract a level of preferential processing in attentional and perceptual domains (see Palermo & Rhodes, 2007 Frischen et al., 2008; for reviews), three main questions are addressed in this chapter. Firstly, is it possible to ignore a face, when effective task performance depends upon this ability, and participants are instructed thus? Secondly, if it is possible to ignore a face, does performance vary according to the valence of the *to-be-ignored* faces? Thirdly, does the search advantage for negative valenced faces persist in conditions of temporal selection? Lastly, as a side issue (and to check the appropriateness of subsequent methodology), this chapter examines whether there are any systematic differences in performance, dependent on observers' prior knowledge of target identity.

3.6.3 *Chapter 6: The time course of preview benefit with positively and negatively valenced faces*

Chapter 6 comprises four experiments which can be considered in two distinct groups. The first group explores the impact of shortening the preview duration from the typical 1000ms presentation seen in the preview search paradigm (e.g., Watson & Humphreys, 1997; 1998) to durations of 250-750 ms. The second group extends the preview from 1000ms to 3000ms. This chapter aims to explore whether valence-based performance differences are demonstrated outside the typical preview duration, and how performance varies across this time course overall. The rationale behind these experiments stems from ecological considerations surrounding processing the emotional face. That is, whether rapid, broad distinctions made between positively and negatively valenced stimuli (i.e. Smith et al., 2003,) and the apparent facial resistance to suppression, may be reflected in the time course of its attentional processing.

3.6.4 *Chapter 7: The effect of facial expression change on time-based selection*

The final set of experiments shifts the focus from the mechanics (so to speak) of preview search with schematic faces, to a more ecological-valid experimental context. As human faces rarely remain static or unchanging in everyday social interaction, this chapter explores the effects of an expression change to a previewed set of neutral faces. Previously, changes that represent a shift in high-level shape or identity have disrupted any performance benefits that arise from previewing a subset of distractors. Thus, the main questions in this chapter are whether a change in facial expression presents a behaviourally-relevant change (i.e. a change that disrupts the preview benefit), and if so, does this vary according to the direction of the change (i.e. to a negative or positive expression)?

3.6.5 *Chapter 8: Conclusions*

The last chapter in this thesis outlines the conclusions that may be drawn from the empirical work described above. Chapter 8 can be divided, broadly speaking, into three sections;

i) A review of the main aims of this thesis and the research questions that have motivated the experimental investigations undertaken, together with an overview of the main findings from each chapter.

ii) A discussion of the impact that these findings may have on the present theoretical framework; both in terms of the preview search literature and current understanding of how faces are processed in visual search-type tasks.

iii) An evaluation of any prospective issues that arise from this thesis; suggesting where further investigation is needed to explore or clarify the findings, and more importantly, how future work might address these issues.

Chapter 4

Visual search with emotionally valenced schematic faces: Does contrast polarity make a difference?

4 Visual search with emotionally valenced schematic faces: Does contrast polarity make a difference?

4.1 Abstract

Schematic faces have been used in a number of visual search experiments and have generally supported the search advantage for negatively valenced faces (e.g., J.D. Eastwood et al., 2001; A.Öhman et al., 2001; E. Fox et al., 2000) However, facial stimuli vary greatly in the schematic representation and the contrast polarity used (e.g., black stimuli on a white background; A. Öhman et al., 2001, or white stimuli on a black background; J.D. Eastwood, et al., 2001). Two experiments compared search performance with schematic faces in these contrast conditions; evaluating whether contrast polarity introduces systematic differences into search performance, and the extent to which any valenced-based search advantage is affected. The search advantage for negative faces persisted in all cases. However, valenced face targets were found more rapidly in the $\text{Black}_{\text{Stimulus}}$-$\text{White}_{\text{Background}}$ condition in both experiments. Moreover when stimuli were inverted (Experiment 2), the negative face targets continued to be detected more rapidly, but only in the $\text{Black}_{\text{Stimulus}}$-$\text{White}_{\text{Background}}$ condition.The implications of these findings were discussed in respect of thesis methodology.

4.2 Introduction

Schematic representations have frequently been adopted as the stimulus of choice in exploring visual search for faces. Despite their visual simplicity, evidence from both behavioural (i.e., McKelvie, 1995) and neuroimaging studies (i.e., Wright et al., 2002; Sagiv & Bentin, 2001) supports the assertion that facial schematics are meaningful, in terms of what they purport to represent (in this instance, facial expression; see Aronoff, Barclay & Stevenson, 1988) and are processed in a manner akin to other representations of faces (e.g., photographs, cartoons or line drawings). Moreover, schematic faces are relatively straightforward to control in terms of their consistent basic features (e.g., Öhman et al., 2001), disambiguity of expression (e.g., Fox et al., 2000) and lack of potential perceptual confounds, such as luminance differences or distinguishing features (see Purcell et al., 1996). This ease of control makes this type of stimulus particularly suitable for achieving the experimental manipulation necessary for examining both the mechanisms underlying temporal selection, and visual attention more generally (see Eastwood et al., 2001).

A wide range of schematic facial stimuli has been used over the last 15 years of visual search experimentation, varying, for the most part, only in their schematic detail. That said, minor variation in facial features (i.e., inclusion of schematic eyebrows, noses or gaze cues: see Öhman et al., 2001; Tipples et al, 2002; Fox et al., 2000, Von Grünau & Anston, 2005) has affected the main research finding little. Faces displaying some form of negative expression (e.g., anger, sadness, fear) are generally detected more rapidly amongst neutral or positive distractor faces, than are their positively valenced counterparts (see Hansen & Hansen, 1988; Hampton et al., 1989; Öhman et al., 2001;

Fox et al., 2000, Eastwood et al., 2001, but cf. Williams et al., 2005b; Juth et al., 2005; Williams & Mattingley, 2006).

The schematic stimuli presented in this study are based on those used by Eastwood and colleagues (2001), with simplistic facial displays consisting of two small circles as eyes, a curved or straight line mouth (upwards curving or downwards curving for positive and negative affect faces, respectively), surrounded by a circular outline. These have been selected for reasons of unambiguous facial valence (negative or positive), lack of extraneous—and possibly confounding—detail (i.e. eyebrows or gaze cues) and prior reliability. However, although these stimuli are also highly similar to those used in other studies (see Fox et al., 2000, 2001; White, 1995) and have demonstrated a robust threat/ negative valence search advantage in those instances, there have been some inconsistencies between studies. That said, for the most part, these inconsistencies relate to aspects of stimulus display variables (e.g., set sizes; contrast polarity, presence of valenced versus non-valenced distractors, variable mapping of targets to distractor sets). Thus, it appears appropriate to evaluate these stimuli in terms of suitability for further use, to i) ensure consistency with previous valence effects; and to ii) assess the effects of varying stimulus displays.

4.2.1 *Criticisms of schematic facial stimuli*

Despite the obvious advantages of using simple, non-ambiguous facial stimuli, the selection of schematic faces for experimental work remains somewhat contentious (e.g., Purcell & Stewart, 2006; Calder et al., 1996), largely due to criticisms of lack of realism and ecological validity. Hortsmann and Bauland (2006) have identified two specific difficulties with these stimuli. Firstly, they argue that the evolutionary rationale for a threat/ negative affect advantage derives from consideration of real faces, rather than schematic ones, and those studies that present the strongest evidence for a threat superiority effect (i.e. Fox et al., 2000), use highly simplified (in their words, "relatively impoverished", p.196) stimuli. This might be taken as questioning how appropriate it is to use simple facial schematics, in any event.

In comparison, empirical studies using more complex schematic representations (i.e. Nothdurft, 1993; Öhman et al., 2001) have elicited an attenuated advantage for threatening (or more generally, negatively valenced) faces; throwing into question the robustness of the effect (particularly since photographic faces present a more complex stimulus still). Moreover, Horstmann and Bauland also assert that any search advantage may emanate from elements of the stimulus not usually associated with real facial expression (for example; the down-turned or "frowning" mouth; see Ekman & Friesen, 1976). In terms of ecological validity or evolutionary relevance, we have no clear way of evaluating which type of (or specific) facial schematic best represents the human face- and which aspects of search advantage are attributable to which features.

In addition, facial schematics lend themselves to the argument that enhanced detection (or preferential processing) of one stimulus over another is driven, not by facial displays of emotion, but by differences in the perceptual features of the stimuli presented. For example, it might be said that the curve of the upwards curving (or smiling) mouth provides less of a perceptual contrast against the outline of the face than the downwards curve; thus, providing a less salient feature for detection (Purcell & Stewart, 2006). Not only would this question any advantage for negative faces based on their affective content, but would also query whether these stimuli are processed holistically (i.e. as a “hallmark” of face processing; see Farah et al., 1998) and consequently, should be deemed sufficiently face-like. Several of these potential confounds are addressed by the schematics selected for this work. In addition, the standard control for search advantage effects that may be based simply on low-level feature differences (i.e. evaluating search with schematic stimuli that have been inverted; see Yin, 1969; McKelvie, 1995; and see below) will be employed.

4.2.2 *Inversion of schematic faces*

Holistic processing has been proposed to be a perceptual mechanism that sets faces aside from other objects (e.g., Farah et al., 1998; but cf. Diamond & Carey, 1986; Gauthier & Tarr, 1997). This phenomenon has been demonstrated via a wide range of experimental paradigms, usually rooted in expression recognition tasks with photographic faces (for example, *composite effects*; Young et al., 1987; *part- whole configuration effects*, Tanaka & Sengco, 1997; *spacing effects,* Haig, 1984; Kemp et al., 1990). Amongst these, the *face inversion effect* (e.g., Yin, 1969; Farah, Tanaka & Drain, 1998) is taken as some of the strongest evidence for a specialized processing mechanism (Duchaine & Youvel, 2008). In the classic study (Yin, 1969), participants learned sets of face and non-face stimuli for subsequent recognition; presented as either upright or inverted in both study and test phases. Despite an accuracy cost for all types of stimuli following inversion; this cost was most pervasive with faces.

Subsequent work has used this principle to provide de facto validation of affective face stimuli in a variety of experimental settings (i.e. Öhman et al., 2001; Eastwood et al., 2001; but cf. Lipp, Price & Tellegen, 2009). The rationale is that, as inversion disrupts the rapid holistic processing of faces (subjecting inverted face stimuli to the analytic, componential processing, typical of non-face objects), differences attributed to preferential processing of negative affect should dissipate, as they are no longer discernible from the stimuli. However, since the component features of the stimuli and their spatial/ configural relationships are identical to those in upright presentation, differences will still be evident if processing advantage is a product of feature differences, rather than affect.

That said, the validity of this measure in respect of both holistic (versus componential) processing and valence-based search advantage (versus simple feature search) has recently been challenged. Lipp et al., (2009) have highlighted several inconsistencies within the literature that, they believe, may stem from differences in stimulus materials (i.e. photographic or schematic faces) and different researchers' conceptualizations of a search advantage (i.e. differences in mean detection time; intercept effects; or search efficiency, demonstrated by search slopes). For example, if we take simple detection times as our metric, Fox et al., (2000) demonstrated a clear face inversion effect (i.e. abolishing the performance difference between negatively and positively valenced faces) with schematic faces, whereas Öhman et al., (2001) found that threatening faces were found faster amongst non-threatening facial stimuli for both upright and inverted stimuli. Using the same measure of search advantage, Ashwin, Wheelwright and Baron- Cohen (2006) and Eastwood et al., (2001) also found a negative superiority effect when their schematic stimuli were inverted (although, for Eastwood and colleagues, this performance difference was no longer evident when search slope data were evaluated; an effect also demonstrated by Williams et al., 2005b; with photographic faces).

This unexpected search advantage for inverted negative faces could be interpreted either as an indication that i) holistic processing is unnecessary for processing emotional expression, or ii) as more commonly argued before (see Purcell & Stewart, 2006), that schematic faces are not processed holistically, and enhanced detection of the "negative mouth" in these stimuli is the source of the search advantage. However, because Lipp and colleagues (2009)—who found differential valence-based processing for both inverted schematic and photographic faces—also evaluated both explicit and implicit processing of affect with their inverted stimuli (and found strong indications that negative faces were still rated as such, despite inversion), we can also argue from their findings that inversion does not prevent access to affective information in facial stimuli. Thus, holistic processing of the face is not necessary for simple affective valence discrimination.

In summary, although there is considerable debate concerning the effects of inversion upon facial schematics, similar findings to Eastwood and colleagues (i.e. that negative search advantage will dissipate upon stimulus inversion) would be predicted, given the similarity of the stimuli and search arrays (e.g., a valenced target face amongst neutral distractor faces). However, taking this debate into account, and the equivocation within Eastwood's study (2001) itself, these findings should be evaluated carefully and with some caution.

4.2.3 *Contrast polarity and facial stimuli*

One variation amongst visual search studies using facial schematics that has not yet been directly addressed, is the contrast polarity of the facial stimuli used (i.e., faces formed from black lines drawn on a white background, or vice versa). This issue straddles several of those outlined above. For example, highly detailed stimuli such as photographs (e.g., Hansen & Hansen, 1988; Williams et al., 2005) or line drawings (e.g., Öhman et al., 2001) and highly simplified schematics (e.g., Eastwood et al., 2001; Fox et al., 2000; White, 1995) have been used in both contrast presentations. However, although findings of negative affect/ threat superiority have persisted for the most part, this is not to say that differences in contrast polarity are not having some impact upon these data.

In this way, two phenomena normally associated with the face processing literature might potentially have some bearing upon the detection of facial expression in the two contrast presentations used. Most obviously, the effect of *photographic negation* (or contrast reversal) may influence how these faces are processed (e.g., Benton, 2009, White, 2001; Galper, 1970). This effect is usually associated with an impaired ability to recognize familiar faces whose contrast polarity has been reversed between study and test (in effect, photographic negation), relative to familiar faces whose contrast polarity remains the same (e.g., Russell, Sinha, Biederman, & Nederhouser, 2006; Vuong, Peissig, Harrison, & Tarr, 2005; Kemp, Pike, White, & Musselman, 1996; Bruce & Langton, 1994).

However, the processing differences evident in dissociable aspects of face processing (i.e., facial identity recognition and expression recognition; see Calder & Young, 2005; and Palermo & Rhodes, 2007; for reviews) have been shown to extend to contrast polarity reversal, with no apparent impairment of expression recognition (e.g., White, 2001). Arguably, this is due to the edge and contour information available in photographic negation being sufficient for recognition of facial expression, but not identity (in contrast to the surface and reflective properties, available in non- negative photographs; i.e. Santos & Young, 2008; Johnston, Hill, & Carman, 1992; Hayes, Morrone, & Burr, 1986). In this study, although detection (and implicitly, recognition) of a particular expression is most relevant, and certainly, equivalent edge-based featural information will be presented in both contrast polarities; it remains a possibility that differences will emerge, that are not yet accounted for in the schematic face literature.

More tenuously, it is possible that viewing a facial stimulus in an unfamiliar contrast polarity might elicit effects similar to the *other race effect* (i.e. more effective learning of own-race faces demonstrated in recognition memory tasks; Chance, Lockwood & Goldstein, 1983; Galper, 1973; Malpass & Kravitz, 1969). In this phenomenon, individuals recognize example faces of their own race more effectively than those of other races; although this is believed to hinge upon the level of exposure to a particular type of face (i.e. familiarity or expertise effects), rather than the race membership of the individual per se (see Duchaine & Youvel, 2008; for an overview). Intuitively, the likelihood of this effect influencing performance in search using schematic faces might appear low. However, given that this effect interacts with other aspects of facial processing (for example, holistic processing; Tanaka, Kiefer, & Bukach, 2004 and inversion effects, Rhodes et al, 1989; but see Valentine & Bruce, 1986), it is possible that this may play a role in the relative efficiency of search in either contrast polarity.

4.2.4 *Purpose of the current chapter*

Three main questions are addressed by the experiments in this chapter: First, does contrast polarity (either white stimuli on a black background, or vice versa) systematically affect search performance for detection of an emotional schematic face? Second, do the schematic stimuli selected elicit any search advantage attributable to facial affect (in line with similar effects demonstrated with other facial stimuli)? And lastly, do these stimuli demonstrate the standard f*ace inversion effect* (within, or across contrast polarity)?

In answering these three questions, these experiments aim to provide validation of the facial schematics used here; in terms of their affective content, their attentional properties, and overall, their suitability for use in the remainder of the studies presented in this thesis. Due to the specific relevance of these findings to the methodology adopted hereafter, and the fact they should be considered apart from the findings of subsequent chapters, these will be discussed in more detail than subsequent chapters at the end of the second experiment.

4.3 Experiment 1: Contrast polarity comparison in visual search with upright valenced schematic faces

Experiment 1 examined visual search for upright positively or negatively valenced face targets amongst upright neutral distractors. Facial stimuli with highly similar features, varying only in their colour (i.e. black or white) were presented on a contrasting white or black background. The experiment aimed to establish whether the typical search advantage for negatively valenced schematic faces (i.e. Eastwood et al., 2001; Fox et al., 2000; Öhman et al., 2001) would be demonstrated with these stimuli. In addition, Experiment 1 served to examine whether varying contrast presentation affected i) search performance in general, or ii) specific valence effects when using facial schematics. In turn, this would allow evaluation of the impact of methodological inconsistencies between previous studies.

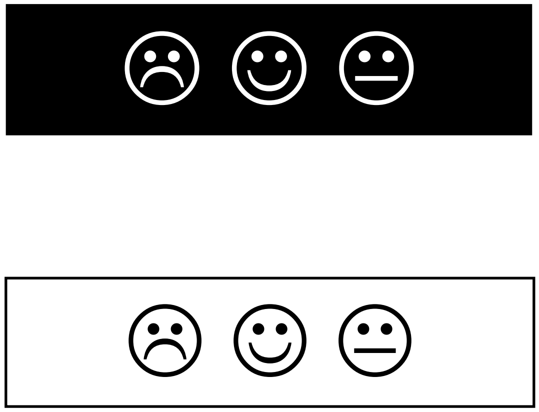
4.4 Method

4.4.1 *Participants*

Twelve students at the University of Warwick (10 female, 2 male) participated for course credit. Participants were aged between 18 and 32 years (M =19.92 years) and 11 were right handed. All participants self-reported normal or corrected-to-normal vision.

4.4.2 *Stimuli and Apparatus*

A Gateway GP6 400 computer was used to present all displays and record participants' responses in this and subsequent experiments. Stimuli were displayed on a 17-inch Gateway VX 700 monitor, with 800 x 600 pixels resolution and 75 Hz refresh rate, positioned at eye-level and at a viewing distance of approximately 60 cm. Stimuli were essentially the same as those used by Eastwood et al. (2001), and similar to those in a number of previous studies (i.e., Fox et al., 2000; Nothdurft, 1993; White, 1995; Horstmann, 2007). All stimuli in the White$_S$ (stimulus) – Black$_B$ (background) contrast presentation were drawn in light grey (RGB values = 200, 200, 200) against a black background. The stimuli in the Black$_S$ – White$_B$ contrast presentation were drawn in black and presented against a light grey background of the same RGB values as above. Targets consisted of positive and negative valenced stimuli, and distractors had a neutral expression (see Figure 4.1).



White$_S$- Black$_B$
contrast condition

Black$_S$-White$_B$
contrast condition

Figure 4.1 Examples of schematic face targets and distractors

All face stimuli had a diameter of 13 mm, subtending a visual angle of approximately 1.2°. Search displays were generated by randomly positioning items within an invisible 6 x 6 matrix with an inter-element display spacing of 75 pixels (approximately 29.25 mm). Stimulus positions were then jittered by up to +/- 4 pixels in both x and y axes. Search displays consisted of display sizes of six, eight, and ten items, divided equally between the right and left sides of the screen, with a valenced target (positive or negative) replacing one of the neutral distractors. This was displayed equally to the left or right of the midline. On catch trials, no target face was present.

4.4.3 *Design and Procedure*

The experiment was conducted in a dimly lit, sound attenuated room and took approximately 45 minutes to complete. Based on a 3 x 2 x 2 within-participant design (Display Size x Contrast x Target Valence), each block comprised 120 experimental trials, and a further 12 catch trials where no target was present. This localization aspect of the task allowed target-present trials to be maximized, which in contrast to target-absent trials are more straightforward to interpret (e.g., Chun & Wolfe, 1996). In addition, these catch trials ensured that participants had to search the entire display before making a response (i.e. the location of the target could not be accurately inferred by its absence on one side of the screen or the other). Where a target was presented, it was located with equal probability to the right or left side of the screen. Each participant completed four blocks of trials (two of each contrast type), with a short practice block of 20 trials preceding each new block. The order of contrast type block was counterbalanced, with alternating Black_S-White_B and White_S- Black_B blocks.

Equal numbers of negative and positive targets were presented, randomly and with equal probability, at each display size. Targets were not presented in the centre two columns of the six-column matrix (i.e., were only presented in columns 1, 2, 5 & 6), to ensure they could be easily distinguished from the midline of the matrix. A trial in the Black_S-White_B condition consisted of a blank screen (1000 ms), followed by a black central fixation dot (2mm x 2mm) for 1000 ms, followed by the search display. The White_S- Black_B condition was identical except for reversal of the stimulus and background contrast presentation. Participants were asked to locate an “odd-one-out” target and indicate whether it was to the left or the right of the screen, as quickly and accurately as possible, by pressing the Z or M key respectively, or make no response if the target was absent. The fixation dot remained visible throughout the trial and participants were asked to remain fixated until the search display appeared. The search display remained on screen until the participant responded or for 6000 ms, after which the next trial was initiated. If an error was made, or no response was made when a target was presented, feedback was given in the form of a short tone (1000 Hz, 500 ms).

4.5 Results

4.5.1 *Reaction time data*

All anticipatory Reaction Times (i.e. < 150 ms) were treated as errors and discarded. Mean correct Reaction Times (RTs) are shown in Figure 4.1 and search slope statistics are shown in Table 4.2. Overall, search was more efficient for negative targets, with no clear advantage for either contrast presentation. A 3 (Display Size) x 2 (Target Valence) x 2 (Contrast Type) within participants ANOVA confirmed that negative targets were detected significantly faster than positive, $F(1,11)=164.64$, $MSE = 6284.36$, $p<.001$, and RTs increased as display size increased, $F(2,22)= 68.57$, $MSE= 5407.07$, $p<.001$.

In addition, there was a significant main effect of Contrast Type, $F(1,11)=10.11$, $MSE= 12303.61$, $p< .05$, with faster detection of black targets presented on a light background (the Black_S –White_B Contrast Condition). However, a significant Target Valence x Contrast Type interaction, $F(1,11) =12.60$, $MSE= 5052.82$, $p<.05$, indicated that this effect was driven by enhanced detection of positive targets in the Black_S –White_B contrast polarity. More importantly, a significant Target x Display Size interaction,

Table 4.1 Search slope statistics for Experiment 1, by contrast type and target valence

	Contrast type and Target valence			
	$Black_S$ –$White_B$ Contrast		$White_S$- $Black_B$ Contrast	
Slope Statistics	Negative	Positive	Negative	Positive
Slope (ms/item)	29.57	51.92	29.91	63.99
Intercept (ms)	628.79	577.46	642.87	581.77
R^2	0.99	1.00	0.95	0.99

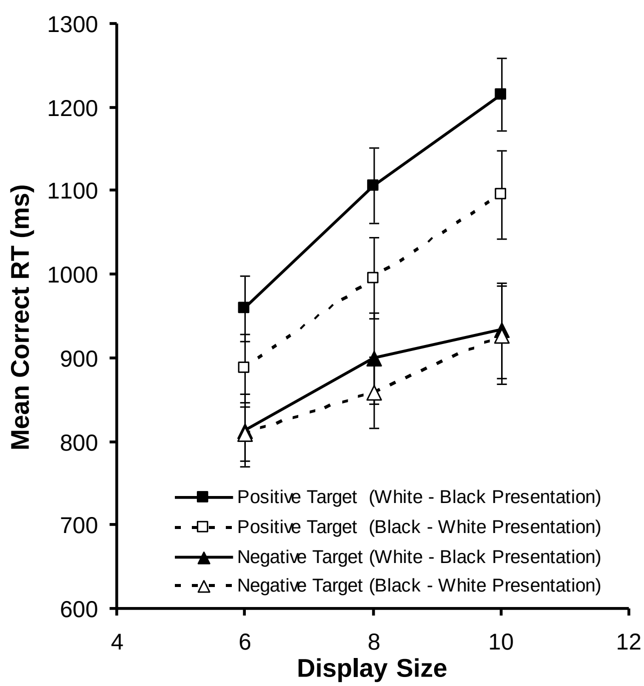


Figure 4.2 Mean correct RTs for detecting positive and negative targets, as a function of contrast polarity and display size for Experiment 1. Error bars indicate ±1 standard error.

F(2,22)=13.58, *MSE*= 2819.22, *p*<.05, confirmed that search slopes were steeper overall for positive targets. However, neither the Contrast Type x Display Size, *F*(2,22)= 0.93, *MSE*= 4664.83, *p*=.41, interaction, nor the three way (Target Valence x Contrast Type x Display Size), *F*(2,22)= 0.78, *MSE*=2683.13, *p*= .47, interaction approached significance.

4.5.2 *Error data*

All error data can be seen in Table 4.2. On search trials, errors were low (0.97 %, for $Black_S$ –$White_B$ contrast; 1.25 %, for $White_S$- $Black_B$ contrast; 1.11 %, overall) and were logarithmically transformed in order to avoid compression issues. These transformed data were then analyzed with a 3 (Display Size) x 2 (Target Valence) x 2 (Contrast type) within-participants ANOVA. There were no significant main effects; Target Valence, *F*(1,11)=1.06, *MSE*=0.09, *p*=0.33, Contrast Type, *F*(1,11)= 2.36, *MSE*= 0.07, *p*=.15, and Display Size, *F*<1, *p*>.64.

In addition, neither the Target Valence x Contrast Type, the Target Valence x Display Size interaction, both *F*s< 1, *ps* >.72, nor the three way interactions, *F*(2,22) = 1.55, *MSE*=0.09, *p*= .23, proved statistically reliable. However, the Contrast Type x Display Size, *F*(2,22)=3.47, *MSE*= 0.07, *p*<.05 interaction was significant, demonstrating a more consistent increase in error rate across display size, in the $White_S$- $Black_B$ condition. Errors on catch trials were also low overall (4.51%, for $Black_S$ –$White_B$ presentation; and 5.90%, for $White_S$- $Black_B$; 5.21%, overall). Although these were higher than search error rates, they showed a strong degree of consistency across display size and contrast presentation. This was confirmed by analysis with a 2 (Contrast Type) x 3 (Display Size) within-participants ANOVA. No significant effects of Contrast Type, $F(1,11)=0.21$, $MSE= 167.30$, $p=0.66$, or Display Size, $F(2,22)=1.44$, $MSE= 85.82$, $p=0.26$, were demonstrated; nor did the Contrast x Display Size interaction, $F(2,22)=1.54$, $MSE= 43.60$, $p= 0.24$, reach significance.

Table 4.2 Mean percentage error rates for Experiment 1, by contrast, target valence and display size

	Display Size			
Contrast Type	*6*	*8*	*10*	*Mean*
$Black_S$ –$White_B$				
Negative Target	0.83	0.42	1.25	0.83
Positive Target	1.88	0.42	1.04	1.11
Catch Trials	4.17	6.25	3.13	4.51
$White_S$- $Black_B$				
Negative Target	0.83	1.04	1.04	0.97
Positive Target	0.63	1.88	2.08	1.53
Catch Trials	9.38	6.25	2.08	5.90

4.6 Discussion

The main purposes of this experiment were; to i) compare search performance in two contrast polarities using upright face schematics, and to ii) establish whether the typical search advantage for negatively valenced faces was evident with these particular stimuli. Search performance in $Black_S$ –$White_B$ contrast (black stimuli, white background) and $White_S$- $Black_B$ contrast (white stimuli, black background) was pertinent to evaluating methodological differences in previous work (and subsequent stimuli selection for this thesis). Assessing any search advantage for the negative valenced facial schematics used in this experiment was more relevant to evaluating the stimulus validity (i.e. whether they were processed in a manner consistent with their affective content, and in line with previous work; e.g., Eastwood et al., 2001; Fox et al., 2000; Öhman et al., 2001).

Faster detection of negative faces than positively valenced faces was demonstrated clearly in both $Black_S$ –$White_B$ and $White_S$- $Black_B$ contrast presentations, although search efficiency for these targets appeared very similar across both contrast conditions. In addition, performance differences attributable to display size (i.e., RT increasing with display size), were broadly similar across contrast presentation; although efficient detection of positive targets was significantly impacted by increasing display size.

That said, an unexpected Contrast Type x Target Valence interaction indicated that detection of positive faces was facilitated by presentation in the $Black_S$ –$White_B$ contrast format. Further, this effect, in turn, appeared to drive significant differences between contrast polarities. Thus, it is possible to suggest a more reliable valence-based search advantage in the $White_S$- $Black_B$ contrast presentation (i.e. an effect that is less influenced by contrast polarity). However, analysis of error rates showed remarkable consistency across all experimental manipulations, suggesting the absence of performance decrements attributable to these factors (in terms of accuracy), and presenting no evidence for a speed/ accuracy trade-off. Potential explanations for this anomalous finding will be discussed below.

4.7 Experiment 2: Contrast polarity comparison in visual search with inverted valenced schematic faces.

This experiment investigated search for inverted positively or negatively valenced face targets amongst inverted neutral distractors. Similarly to Experiment 1, displays comprised either light faces on a black background ($White_S$- $Black_B$ contrast) or black faces on a light background ($Black_S$ –$White_B$ contrast). However, in this instance, facial stimuli were inverted to examine whether the search advantage for negative faces, observed in Experiment 1, might be attributable to feature differences, rather than preferential processing of negative facial affect per se. If so, differences in search performance would have persisted, whereas, differences stemming from differential processing of negative expression should be abolished with stimulus inversion. In addition, performance differences were evaluated between contrast presentation format to assess whether this factor contributes to or interacts with any valence-based effects in search performance.

4.8 Method

4.8.1 *Participants*

Twelve students at the University of Warwick (eight female, four male) participated for course credit. Participants were aged between 18 and 28 years (*M*=21.42 years) and nine were right handed. All participants self-reported normal or corrected-to-normal vision.

4.8.2 *Stimuli and Apparatus*

All stimuli and apparatus were identical to that detailed in Experiment 1 above, with the exception that all stimuli were inverted.

4.8.3 *Design and Procedure*

The design and procedure of this experiment were identical to that described above in Experiment 1.

4.9 Results

4.9.1 *Reaction time data*

All anticipatory RTs (< 150 ms) were treated as errors, and discarded accordingly. Mean correct RTs are shown in Figure 4.3 and search slope statistics in Table 4.3. A 3 (Display Size) x 2 (Target Valence) x 2 (Contrast Type) within-participants ANOVA confirmed a significant main effect of Contrast Type, $F(1,11)=9.64$, $MSE= 6837.04$, $p<.05$, with more rapid detection of targets evident in the Black_S –White_B contrast.

Moreover, RTs increased significantly as Display Size increased, $F(2,22) = 47.46$, $MSE = 3494.44$, $p<.001$. However, contrary to predictions, negative targets were detected significantly faster than positive, $F(1,11) = 57.94$, $MSE = 18738.72$, $p<.001$, which might be attributable to the particularly efficient detection of inverted negative faces in the Black_S –White_B contrast polarity. Indeed, a significant Contrast Type x Target Valence interaction supported this interpretation, $F(1,11) = 25.42$, $MSE=3336.72$, $p<.001$. A significant Target Valence x Display Size was also demonstrated, $F(2,22) = 4.66$, $MSE = 3742.85$, $p<.05$, with steeper search slopes evident for detection of inverted positive targets. That said, neither the Contrast Type x Display Size interaction, $F(2,22)=0.23$, $MSE = 3674.76$, $p = .80$, nor the three way Contrast Type x Target Valence x Display Size interaction, $F(2,22) = 1.13$, $MSE=2360.99$, $p = .34$, approached significance.

4.9.2 *Effects of valence on search efficiency*

Given the unexpected effects of target valence detailed above (and the similarity to RT effects seen with inverted schematics in Eastwood et al., 2001), search slope data was analysed to ascertain whether the differences evident in the RT data were also discernible in terms of overall search efficiency. A 2 (Target Valence) x 2 (Contrast Type) within-participants ANOVA showed no significant effect of Contrast polarity, $F(1,11) =0.67$, $MSE = 317.72$, $p = .43$, although, a main effect of Target Valence persisted, $F(1, 11) = 9.28$, $MSE = 452.25$, $p<.05$. In addition, a non-significant Target x Contrast interaction, $F(1,11) =3.53$, $MSE=$

Table 4.3 Search slope statistics for Experiment 2, by contrast type and target valence

	Contrast type and Target valence			
	$Black_S$ –$White_B$ Contrast		$White_S$- $Black_B$ Contrast	
Slope Statistics	Negative	Positive	Negative	Positive
Slope (ms/item)	14.39	40.09	25.59	37.28
Intercept (ms)	623.68	543.18	528.31	656.95
R^2	0.97	1.00	0.97	1.00

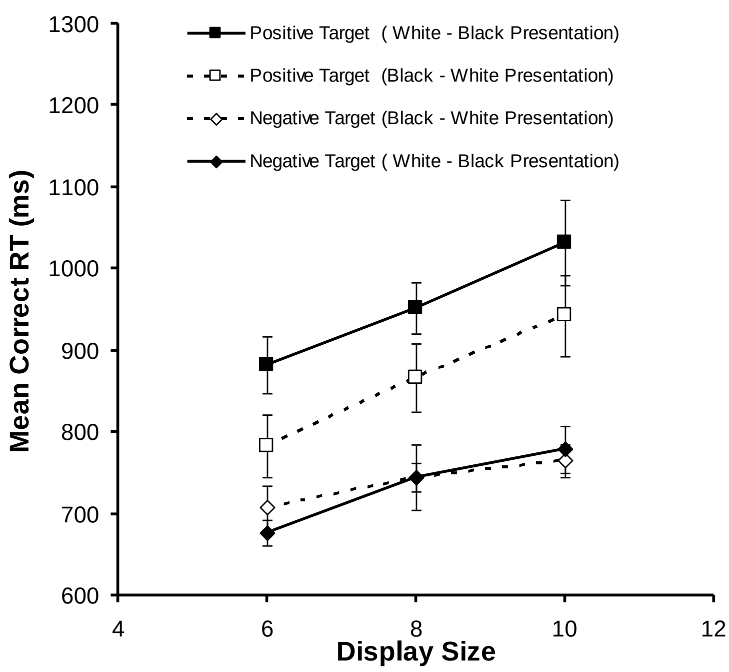


Figure 4.3 Mean correct RTs for detecting inverted positive and negative targets, as a function of contrast polarity and display size for Experiment 2. Error bars indicate ±1 standard error.

166.88, p= .09, was suggestive of a trend towards more pronounced differences in valence effects for Black_S –White_B trials.

In order to examine this trend in more detail, two paired sample t-tests were conducted across contrast polarity conditions (i.e. comparing target valence effects within a particular contrast polarity). These revealed a highly significant difference in search efficiency between negative and positive faces in the Black_S –White_B contrast polarity; $t(11)= 4.48$, $p< .001$, but there was no valence- based difference in search efficiency demonstrated in the White_S- Black_B condition, $t(11)= 1.81$, $p = .10$.

4.9.3 *Error data*

All error data can be seen in Table 4.4. Error rates on search trials were low overall (0.94% for both contrast presentations), and were logarithmically transformed in order to avoid compression issues. These transformed data were then analyzed with a 3 (Display Size) x 2 (Target Valence) x 2 (Contrast type) within-participants ANOVA. No significant main effects were shown; Contrast Type and Display Size, both $Fs < 1$, both ps>.60; Target Valence, $F(1,11)=3.44$, MSE= 0.12, p= .09. In addition, no interactions approached statistical significance; Target Valence x Contrast Type, Target Valence x Display Size , Contrast Type x Display Size, and Contrast Type x Target Valence x Display Size , all Fs <1.8, all ps>.18.

Errors on catch trials were also low overall (0.59%). These data were also log- transformed and were analysed with a 2 (Contrast Type) x 3 (Display Size) within- participants ANOVA. There was no significant main effect of Contrast

Table 4.4 Mean percentage error rates for Experiment 2, by contrast type, target valence and display size

Contrast Type	Display Size *6*	*8*	*10*	Mean
$Black_S$ –$White_B$				
Negative Target	0.42	1.04	0.42	0.63
Positive Target	1.25	1.25	1.25	1.25
Catch Trials	0.31	0.21	0.21	0.63
$White_S$- $Black_B$				
Negative Target	1.46	0.21	0.21	0.63
Positive Target	1.25	1.04	1.46	1.25
Catch Trials	0.42	0.31	0.63	0.45

Type, $F(1,11)=2.20$, $MSE= 0.03$, $p=.17$. However, the main effect of Display Size, $F(2,22)=3.58$, $MSE= 0.02$, $p=.05$, proved significant; possibly driven by a higher error rate in the Black_S –White_B trials at display size 8 (approximately double thevalue of the next highest error rate; White_S- Black_B contrast at display size 10). The Contrast Type x Display Size interaction, $F(2,22)=3.59$, $MSE= 0.04$, $p=.05$, also achieved significance, unsurprisingly, considering the effects of the anomalous catch error rate described above.

4.10 Discussion

This experiment aimed primarily to evaluate the effect of stimulus inversion using facial schematics based on those of Eastwood et al. (2001), presented in two contrast polarity conditions. Two questions were addressed: does contrast polarity affect search performance with inverted face stimuli? In addition, does the negative face search advantage (seen in Experiment 1) persist when the facial schematics are inverted? The findings were clear on some aspects of these questions, whereas others remained more ambiguous.

Firstly, effects of contrast polarity were clearly demonstrable under conditions of stimulus inversion. Differences between the White_S- Black_B and Black_S –White_B contrast formats were relatively robust, with faster overall detection of black targets presented on a light background. That said, a Contrast x Display Size interaction failed to achieve significance, indicating that search efficiency (i.e. search slopes) did not differ between the two polarities.

The effects of stimulus inversion on the valence-based search advantage (seen in Experiment 1) were less clear. In the RT data, a strong effect of Target Valence was demonstrated (recall that in this condition, inversion might distort perception of facial expression), with inverted negative faces detected more rapidly than inverted positive ones. Moreover, the Target x Display Size and Contrast x Target interactions in RTs emphasized (respectively) the steeper search slopes for inverted positive faces, particularly in the Black_S –White_B condition. However, two things should be noted here: firstly, in their study, Lipp and colleagues (2009) only found an impact of stimulus inversion with smaller set sizes (less than six items); that is, in search arrays with larger numbers of items, valence-based differences were evident, regardless of inversion or non-inversion. Although Lipp et al., (2009) stressed that this finding should be considered with caution, it may be that the Target x Display Size interaction in this experiment indicates a similar effect. In addition, it should also be noted that the Contrast x Target interaction was greatly diminished, with evidence of a weak trend only, in subsequent post-hoc slope data analysis. This indicated that search efficiency was broadly equivalent.

However, most strikingly, post-hoc comparisons of search efficiency across contrast polarity showed a highly significant difference between valences in the Black_S – White_B presentation, but no statistically reliable difference in the White_S- Black_B format. This result is somewhat suggestive of a differential influence on the processing of inverted schematic face stimuli, according to contrast polarity. These findings, together with the implications for further work in this thesis, are discussed more fully below in the Conclusions section below.

4.11 Conclusions

The focus of these experiments was threefold; firstly, to examine the effects of varying contrast polarity in search using schematic emotional faces; secondly, to determine whether the search advantage pertaining to negative affective faces would be demonstrated in this instance, and thirdly, to establish whether the inversion of these facial stimuli would affect search performance in general, and more particularly, valence-based differences in performance. Taken as whole, this study aimed to assess the reliability of the facial schematics designed for this body of research from a number of theoretical perspectives, and thus, to ascertain their suitability for further use.

4.11.1 *Summary of findings*

The findings with respect to the first issue of interest (the effect of contrast polarity) were relatively unequivocal. Distinct differences in RT were demonstrated between the two contrast conditions, with more rapid detection of targets being shown in the Black_S –White_B polarity in both experiments. However, in both Experiment 1 and 2, this overall RT advantage failed to translate into differences evident in search efficiency (i.e. search slopes were broadly equivalent across both contrast polarities). Moreover, the interaction of contrast polarity and valence proved particularly interesting; for example, simple RT advantage was evident for upright positive targets in the Black_S –White_B contrast condition, whereas no analogous effect was demonstrated in the White_S-Black_B Presentation. Potential explanations for this and other points of interest identified within the findings are discussed below.

In respect of valence-based effects, it is possible (considering the results of Experiment 1) to support the established search advantage for negative faces. More efficient detection of negative faces was demonstrated both in RT differences and search efficiency evaluation. However, these (arguably) valence-based effects were also evident in Experiment 2, where stimuli were inverted and presumably, facial expressions should have been more difficult to recognize or process (cf. Lipp et al., 2009; Hunt, Cooper, Hungr, & Kingstone, 2007).

Moreover, as in some cases, inverting a face stimulus is used as a control for the existence of valence-driven (as opposed to feature-driven) advantage in visual search (i.e. Eastwood et. al. 2001; Fox et al., 2000), at first glance, this would appear to undermine the validity of our schematics. Further, this surprising finding would appear particularly salient in view of a failure to replicate Eastwood and colleagues' inverted face experiment (2001, see Experiments 1B and 2B). That said, despite a substantial RT advantage for inverted negative targets in for both contrast polarities, when this effect was examined in terms of search efficiency, search slope differences were only discernible between targets valence when presented in the $Black_S$ –$White_B$ contrast polarity. Thus, this demonstrated a face inversion effect in the $White_S$- $Black_B$ contrast, replicating Eastwood and colleagues' findings (2001).

However, in more general terms, inverting the facial schematic did not appear to attract any particular behavioural costs (cf. Prkachin, 2003). In fact, simply comparing numerically between search slope functions in each orientation indicates reduced search efficiency when stimuli were presented in upright orientation. In turn, this would seem to support a more general assertion that these facial schematics were processed as face-like stimuli in this instance, since inverting the stimuli appeared to allow rapid distinction of targets (presumably on the basis of unique feature; i.e. a curved line amongst straight lines). The wider implications of these results, and their impact on the methodology of this thesis are discussed below.

4.11.2 *The effect of contrast polarity on visual search for schematic emotional faces*

The overall trend of differential effects of contrast polarity was not difficult to observe in these two experiments. In both instances, face targets were found more rapidly in the $Black_S$ –$White_B$ contrast condition than the reverse. Although it might be possible to explain this advantage by the operation of some form of familiarity or expertise effects (e.g., Farah et al., 1998; Diamond & Carey, 1986), potentially attributable to a mechanism akin to the other race effect (e.g., Michel et al., 2006; Farah et al., 2004; Rhodes et al., 1989;) or the contrast effects evident in photographic negation (e.g., Benton, 2009; White, 2001; Galper, 1970), it is not possible to differentiate between them at this juncture.

Moreover, it is possible to argue that any further distinction is superfluous; given that there is enhanced performance associated with faces presented in a particular contrast polarity, it may be sufficient to account for this facilitated processing via a general face familiarity or expertise mechanism. Alternatively, it is possible to argue that this advantage is attributable to a *more generalized* familiarity or expertise effect; modern humans simply may be more adept at processing dark stimuli presented on a lighter background because they are more frequently exposed to this contrast polarity (for example, note the contrast of this document).

The impact of contrast polarity on valence-based search performance is harder to interpret. Detection of positively valenced faces in the $Black_S$ –$White_B$ contrast was enhanced compared to performance in the $White_S$- $Black_B$ presentation (Experiment 1).

It is possible that, without the benefit of the additional performance advantage conferred by an adaptive threat detection mechanism (e.g., Öhman & Mineka; 2001; LeDoux, 1996, 1998), any familiarity or expertise with stimuli presented in the Black_S –White_B contrast becomes more effective; it may be that the presence or absence of a negatively valence face serves to modulate this effect. However, the impact of this finding in the current context is only important insofar as it informs future methodology.

4.11.3 *Evidence for valence-based effects*

The evidence for valence-based processing was clear in this instance; the search advantage for negatively valenced faces was strongly demonstrated in both experiments. Thus, from the standpoint of straightforward evaluation, we can assert that these stimuli display the necessary facial attributes to be processed according to the affect intended to be conveyed (i.e. negative valence via a sad schematic face, and vice versa). In turn, this suggests that these stimuli are suitable for use in subsequent work. That said, the interactions of valence with contrast polarity in both upright (see Experiment 1) and inverted (see Experiment 2) orientation, cast some doubt on this assertion. If preferential processing of negatively valenced faces (in schematic representation) is mediated, not by an adaptive mechanism that guides visual attention to possible sources of threat (e.g., Öhman & Mineka; 2001; LeDoux, 1996,1998), but by simple feature differences in the schematic representations, these interactions might indicate some equivocation of imputed valence-based processing.

One possible counter argument against this being an instance of feature-based processing lies in the RT and search slope data; whilst negatively valenced faces are detected more rapidly, search remains relatively inefficient by standards established in general visual search methodology (see Wolfe, 1998; for a review). Given that search performance driven by detection of simple features is likely to attract greater search efficiency, this relative drop in search performance indicates that search performance is dependent on more complex processing than would be expected with differentiation between features. Moreover, this viewpoint is also consistent with the argument that faces are not a stimulus that is available for preattentive processing (e.g., Wolfe & Horowitz, 2004).

4.11.4 *Face inversion effects*

These data were somewhat surprising when we consider established face inversion effects (i.e. Yin, 1969; McKelvie, 1995), and the abolition of valenced-based differences in search performance seen with inverted facial schematics similar to the ones used in these experiments (i.e. Fox et al., 2000; Eastwood et al., 2001). That said, face inversion effects were not without equivocation in Eastwood's (2001) work either; whilst inverted negative faces were still detected faster (i.e. there was an intercept effect), there were no significant differences between the search slope functions (i.e. search efficiency for negative and positive face targets did not differ). This finding was replicated in the White_S- Black_B contrast polarity in Experiment 2.

Face inversion effects are frequently taken as indication that the holistic representation—believed to be characteristic of face processing (e.g., Farah et al., 1998)—has been disrupted, and as evidence that differences in search performance attributed to enhanced detection of one target valence over another, are not the product of low level feature differences (i.e. detection of an upwards curving mouth versus a downwards curving mouth). However, recent work (Lipp et al., 2009) has cast considerable doubt over the homogeneity of the face inversion literature as it pertains to visual search.

Firstly, Lipp and colleagues have suggested that the methodological differences (i.e. set sizes, performances measures, facial stimuli) between visual search studies using inverted faces mean it is difficult to consider the literature as a coherent whole. Secondly, they assert that the affective information communicated by facial expression continues to be conveyed upon inversion, on the basis of both explicit and implicit measures of affective evaluation. Although previously, it has been generally assumed that face inversion disrupts holistic processing (and thus, impairs access to the affective content of the stimulus), previous work has also acknowledged that this might not be the case. For example, Hunt et al., 2007 underwent a series of measures designed to "camouflage" the nature and valence of their inverted stimuli (e.g., using strategic lines added to schematics, and describing inverted faces as other objects; e.g., mushrooms, goblets) to counteract any residual facial/ affective processing.

Finally, we might question whether comparing search performance in upright and inverted orientations is an appropriate way of evaluating the operation of characteristic face-processing mechanisms, in any event. For example, Suzuki and Cavanaugh's (1995) work, in which the researchers compared global and local processing of arcs arranged either to resemble faces or scrambled patterns, indicates that global processing (i.e. of a face-like configuration) can restrict access to even a simple salient feature (e.g., a curved line). Thus, when a face-driven mechanism, such as holistic processing, dominates the perceptual processing of the stimulus (i.e. when presented in an upright orientation), search differences could be attributed to the holistic (or global) representation of that stimulus.

Conversely, disrupting that mechanism of processing might preclude the operation of valence-based effects. However, that is not to say that feature-driven effects, usually attenuated by global or holistic processing in upright orientation, could not dominate when the same stimulus is inverted (e.g., enhanced salience of a curved line, that does not follow the contour of the face outline). Thus, an equivalent effect could be demonstrated, for an entirely different reason; and in this instance, we would not be able to differentiate between the two effects.

In terms of these data, given that differential processing of inverted stimuli (in terms of RT and search efficiency differences) is only demonstrated in one contrast polarity (i.e. where a black stimulus is shown on a white background), we might assert that differences in search performance are attributable to an artefact of the Black_S – White_B contrast polarity (as discussed above). Moreover, since performance in the White_S- Black_B contrast polarity replicates that demonstrated in Eastwood et al.'s study (2001), we can consider outstanding questions regarding the validity of face inversion effects in evaluating valence-based/ holistic processing as a suitable focus for future work, rather than relevant to this.

4.11.5 *Implications for thesis methodology*

In terms of practical choices for future work, the results were relatively unequivocal. Reflecting the three questions posed empirically, it was necessary to establish the following to ensure suitability of the facial schematics used: i) was there a systematic difference in search performance according to the contrast polarity that would impact on subsequent stimulus presentation? ii) were the facial schematics processed in accordance with their purported affective content? And finally, iii) was there evidence of processing typical of the stimulus type (i.e. were these schematics processed in the same way as other faces?)

Answering these questions was straightforward. Yes, there were performance differences between the two contrast polarities that were reflected in search performance; yes, the stimuli attracted the negative face search advantage predicted from the literature, and yes, these stimuli appeared to be processed by the visual system in the way we would expect faces to be processed. Moreover, from these findings, it is relatively easy to fix upon the most appropriate stimuli for future work.

However, in some ways, it is possible to say that the interactions between the factors tested (e.g., target valence, contrast polarity) have been even more interesting in terms of the way they emphasize disparities in the literature (and present a challenge to the assumption that the literature can be evaluated as a homogenous body of work). In turn, this presents a number of opportunities for further work and considerable insight into issues that remain debated within the field (e.g., application of face inversion effects across all facial stimuli). More practically, several of these interactions have allowed certain stimuli presentations to be discounted, due to the presence of effects that may, in fact, be artifacts arising from other face-processing mechanisms (i.e. holistic processing, expertise effects).

In summary, and for clarity in respect of the methodology of this thesis, it is possible to make the following assertions:

1) The facial schematics used in these two experiments are processed according to their affective content.

2) The facial schematics used in these two experiments are processed by the visual system in the same way as one would expect other facial stimuli to be processed.

3) The White$_S$- Black$_B$ contrast polarity is the most appropriate for future empirical work in this thesis. This is due to i) their demonstration of the strongest / most reliable valence effects, and ii) the presence of a solid Face Inversion Effect upon valence-based processing.

Chapter 5

Emotionally valenced schematic faces in preview search

(This chapter has been adapted from the paper “Visual marking and facial affect: Can an emotional face be ignored?” accepted for publication in *Emotion.)*

5 Emotionally valenced schematic faces in preview search

5.1 Abstract

Previewing a set of distractors allows them to be ignored in a subsequent visual search task (D. G. Watson & G. W. Humphreys, 1997). Five experiments investigated whether this *preview benefit* can be obtained with schematic emotional faces and whether negative and positive facial expressions differ in the extent to which they can be ignored. These experiments examined the preview benefit with neutral, negative and positive previewed faces and showed that a partial preview benefit occurs with face stimuli, but that the valence of the previewed faces has little impact on the extent to which the preview can be ignored. In addition, the absence of a full preview benefit suggests that emotionally valenced faces are difficult to suppress completely, and in turn emphasizing the ecological sensitivity of the mechanism underlying the preview benefit.

5.2 Introduction

The importance of the face and facial expression is emphasized by a body of research that points to its special status within human visual processing (e.g. Tsao & Livingstone, 2008; Vuilleumier & Pourtois, 2007; Kanwisher et al., 1997; Ellis, Bruce & De Schonen, 1992; see Calder & Young, 2005, for a recent review of face processing research). This does not appear to be limited to rapid and efficient processing at the focal point of attention in the visual system, (e.g., Cooper & Langton, 2006, Eimer & Holmes, 2002, 2007; Hairiri et al., 2002) but extends to processing outside conscious awareness, when attention is purposefully directed elsewhere (e.g. Stenberg, Wilking & Dahl, 1998; Morris, Öhman & Dolan, 1998; Mogg & Bradley, 1999; Eastwood, Smilek & Merikle, 2003; Vuilleumier & Schwartz, 2001; Vuilleumier et al., 2001). Moreover, this preferential processing applies to a broad range of facial stimuli (e.g. Kanwisher et al., 1997; Sagiv & Bentin, 2001), even when the face stimulus is simplified into line drawings (e.g. Öhman et al., 2001) or a highly schematic representation (e.g. Eastwood et al., 2001; Fox et al., 2000; White, 1995; Nothdurft, 1993).

Taken as a whole, the apparent breadth and flexibility of this face prioritization mechanism is highly likely to be adaptive, not only due to the high-level social significance of face and facial expression processing, but also its potential relevance to an organism's survival. The adaptive value of this preferential processing is also signaled by its ability to distinguish between qualitatively different social signals. For example, expressions that signal potential threat to an individual (i.e. expressions of anger, fear or distress), are processed faster than either emotionally neutral faces or those displaying positive affect (e.g. Eastwood et al., 2001; Hansen & Hansen, 1988, Hampton, et al., 1989; Fox et al., 2000; Öhman et al., 2001).

Much of the previous research in this area has focused on the ability of negative valenced stimuli (particularly faces) to efficiently attract attention to themselves, within the visual search paradigm (e.g. Hansen & Hansen, 1988; Hampton et al, 1989; Purcell et al., 1996; Eastwood et al., 2001). This methodology is particularly suited to evaluating the differential ability of valenced stimuli to guide or attract attention (Eastwood et al., 2001) in that, the ease of detecting different valenced targets embedded amongst distractors can be directly compared via their RT-display size search slopes (Smilek et al., 2000). There is an obvious adaptive advantage to the efficient detection of stimuli that signify threat. However, it is less obvious why negatively valenced stimuli might continue to dominate selective attention if further processing indicates that they are irrelevant to the current goals of the observer (or currently pose no realistic threat). This would be particularly true when explicit instruction is given to attend to another aspect of a task.

Nonetheless, a number of studies using cueing (e.g. Georgiou et al., 2005; Fox et al., 2001; Fox, Russo & Dutton, 2002), flanker (e.g., Fenske & Eastwood, 2003, Horstmann et al., 2006), and other paradigms (e.g. Eastwood et al., 2003; Vuilleumier & Schwartz, 2001) suggest that a negative affect superiority persists even when the affective nature of the stimuli is irrelevant to the task. For example, Fenske and Eastwood (2003) reported a significantly reduced flanker compatibility effect when negatively valenced faces were displayed, in comparison with positively affective stimuli, which, in turn was abolished once the stimuli were altered to disrupt facial affect. Similarly, Eastwood et al., (2003) found that it took longer to count the component features of schematic faces when these were presented as part of a negative face, in comparison with both positive and neutral faces. However, when faces were inverted to prevent holistic processing (Farah, Tanaka & Drain, 1995; Yin, 1969), differences between neutral, positive and negative faces disappeared, despite preserving features identical to the upright faces.

In general terms, any emotionally valenced stimuli appear difficult to ignore (e.g. Pratto & John, 1991; Sternberg et al., 1998) and unsurprisingly, considering their adaptive salience, faces seem particularly resistant to suppression (e.g. Lavie et al., 2003). Furthermore, Lavie et al., (2003) suggested that distractor faces may require mandatory processing, providing an exception to perceptual load theory (Lavie, 1995, 2000), where successful task performance relies upon the ability to ignore distractors. These findings suggest that the processing of emotional valence in upright faces is automatic and is unlikely to be modified by top-down goals.

Overall, the attentional capture and engagement properties of negatively valenced stimuli appear robust and wide-ranging. In contrast, much less is known about the converse: whether it is possible to deliberately ignore potentially attention-grabbing stimuli over time, for example actively suppressing facial or valenced distractors.

5.2.1 *Time-based visual selection*

Previous work has shown that time of appearance can be used as a selection cue. In particular, observers are able to ignore old stimuli that have been previewed and selectively attend to new items that appear at a later point in time – the *preview benefit* (Watson & Humphreys, 1997, 1998). Typically in the preview paradigm, one set of irrelevant to-be-ignored distractors is presented for 1 second before the remaining search items. The target, when present, appears in the second set of items. The participant's task is to try to ignore the first set of stimuli and search through the second set to detect the target. Search efficiency in the preview condition can be assessed by comparing performance with a full element baseline (FEB) in which all the items appear simultaneously and a half element baseline (HEB)[7] which consists of only the second set of items from the preview condition.

Watson and Humphreys (1997) found that search in the preview condition matched that of the HEB and was reliably more efficient than that in the FEB. Thus, observers appeared to be able to restrict their search to the new items. Several theories have emerged to account for the preview benefit. These include: the top-down limited capacity inhibition of the old stimuli (Visual marking; Watson & Humphreys, 1997; for an overview see Watson, Humphreys & Olivers, 2003), automatic capture by the abrupt onsets associated with the new items (Donk & Theeuwes, 2001, 2003), and the segregation and selective attention to temporally distinct groups (Jiang, Chun & Marks, 2002).

5.2.2 *Purpose of the current chapter*

The investigations in this chapter addressed three main questions: Firstly, it aimed to establish whether observers can effectively ignore old (previewed) face stimuli. Given the numerous reasons why facial stimuli are important to us, it is quite possible that faces simply cannot be ignored. Second, was to determine whether facial valence

[7] This has the effect of reducing the search slope function (i.e. by halving the value of the true slope) for this condition. However, it remains the most appropriate method to ascertain search efficiency, *if observers are completely able to ignore previewed items.*

influences the ability to ignore faces. If negative stimuli are particularly potent within the attentional system, then they might be much more difficult to ignore than positively valenced stimuli. Finally, it aimed to establish whether the typical advantage for negative stimuli (i.e., as search targets) would persist under temporal selection conditions.

Throughout the present work, schematic face stimuli were used, as opposed to more realistic line drawings or photographic stimuli. For the initial establishment of the basic properties of time-based selection with faces, these appeared to be the most appropriate stimuli. Given that schematic faces are relatively straightforward to control in terms of their basic features (e.g., Öhman et al., 2001), disambiguity of expression (e.g., Fox et al., 2000) and lack of potential perceptual confounds, such as luminance differences or distinctive features (see Purcell et al., 1996), this type of stimulus seemed particularly suitable for the experimental manipulation required (see also Eastwood et al., 2001). Considering then, that schematic face stimuli effectively communicate their emotional content (e.g., Aronoff, Barclay & Stevenson, 1988; McKelvie, 1973), and demonstrate equivalent neural correlates to photographed faces (Sagiv & Bentin, 2001), these benefits render them most appropriate for use in the present work.

5.3 Experiment 3: Preview Search with valenced targets and neutral distractors

Experiment 3 examined preview search for positively or negatively valenced schematic face targets amongst neutral face distractors. These types of stimuli are known to produce a negative valence advantage in standard visual search tasks (e.g, Eastwood et al., 2001). Thus Experiment 3 served to establish whether a basic preview benefit occurred with face stimuli, and whether the usual advantage for negative faces would persist during time-based selection conditions.

5.4 Method

5.4.1 *Participants*

Eighteen students at the University of Warwick (16 female, 2 male) participated in this study, either for payment or course credit. Participants were aged between 18 and 21 years (*M*=19.72 years), and 17 were right handed. All participants self-reported normal or corrected to normal vision.

5.4.2 *Stimuli and Apparatus*

A Gateway GP6 400 computer was used to present all displays and record participant responses in this and subsequent experiments. Stimuli were displayed on a 17 inch Gateway VX 700 monitor, with 800 x 600 pixels resolution and 75 Hz refresh rate, positioned at eye-level and at a viewing distance of approximately 60 cm. Stimuli were essentially the same as those used by Eastwood et al., (2001), and similar to those in a number of previous studies (i.e., Fox et al., 2000; Nothdurft, 1993; White, 1995; Horstmann, 2007). All stimuli were drawn in light grey (RGB values = 200, 200, 200) against a black background. Targets consisted of positive and negative valenced stimuli and distractors had a neutral expression (see Figure 5.1).

Figure 5.1 Examples of schematic face targets and distractors

All face stimuli had a diameter of 13 mm, subtending a visual angle of approximately 1.2°

Search displays were generated by randomly positioning items within an invisible 6 x 6 matrix with an inter-element display spacing of 75 pixels (approximately 29.25 mm). Stimulus positions were then jittered by up to +/- 4 pixels in both x and y axes. HEB displays consisted of display sizes of 2, 4, 6 and 8, divided equally between the right and left sides of the screen, with a valenced target (positive or negative) replacing one of the neutral distractors. The target was displayed equally to the left or right of the midline. FEB and Preview displays (i.e. the final search array in the preview condition) consisted of total display sizes of 4, 8, 12 and 16, with a valenced target, when present, replacing a distractor. On catch trials, no target face was present.

5.4.3 *Design and Procedure*

The experiment was conducted in a dimly lit, sound attenuated room and took approximately 1 hour to complete. The experiment was based on a 3 (Condition: HEB, FEB, Preview) x 4 (Display size) x 2 (Target Valence: positive or negative) within-subjects design. Each search condition was run in a separate block of 160 experimental trials with a further 16 catch trials, where no target was present (Experiment 1, Section 4.4.3; see also Watson, Braithwaite, & Humphreys, 2008; Allen, Humphreys, & Mathews, 2008; for use of this methodology with a preview search task). Within a block, equal numbers of negative and positive targets were presented, at each display size. On half the number of search trials, the target was on the left and on the remainder, on the right. Targets were not presented in the centre two columns of the matrix (i.e., were only presented in columns 1, 2, 5 & 6), to ensure that they could be easily distinguished from the midline of the display (and RTs were therefore not influenced by difficulty in differentiating between the sides of the screen). Trial order was randomized within a block and the order of search conditions was fully counterbalanced. Each participant completed one block of trials per search condition, with a practice block of 20 trials preceding each condition. A trial in the HEB and FEB conditions consisted of a blank screen (1000 ms), followed by a light grey central fixation dot (2mm x 2mm) for 1000 ms, followed by the search display. The preview condition was similar, except that half of the distractors were presented for 1000 ms before the second set which contained the target when present (see Figure 5.2).

Participants were asked to locate an *odd-one-out* target and indicate whether it was to the left or the right of the display center by pressing the Z or M key respectively, or to make no response if the target was absent. The fixation dot remained visible throughout the trial and participants were asked to remain fixated until the final search display appeared. In the preview search condition, participants were instructed to ignore the first display (which contained distractors only), and to search through the subsequently added new items, which would contain the target (when present).

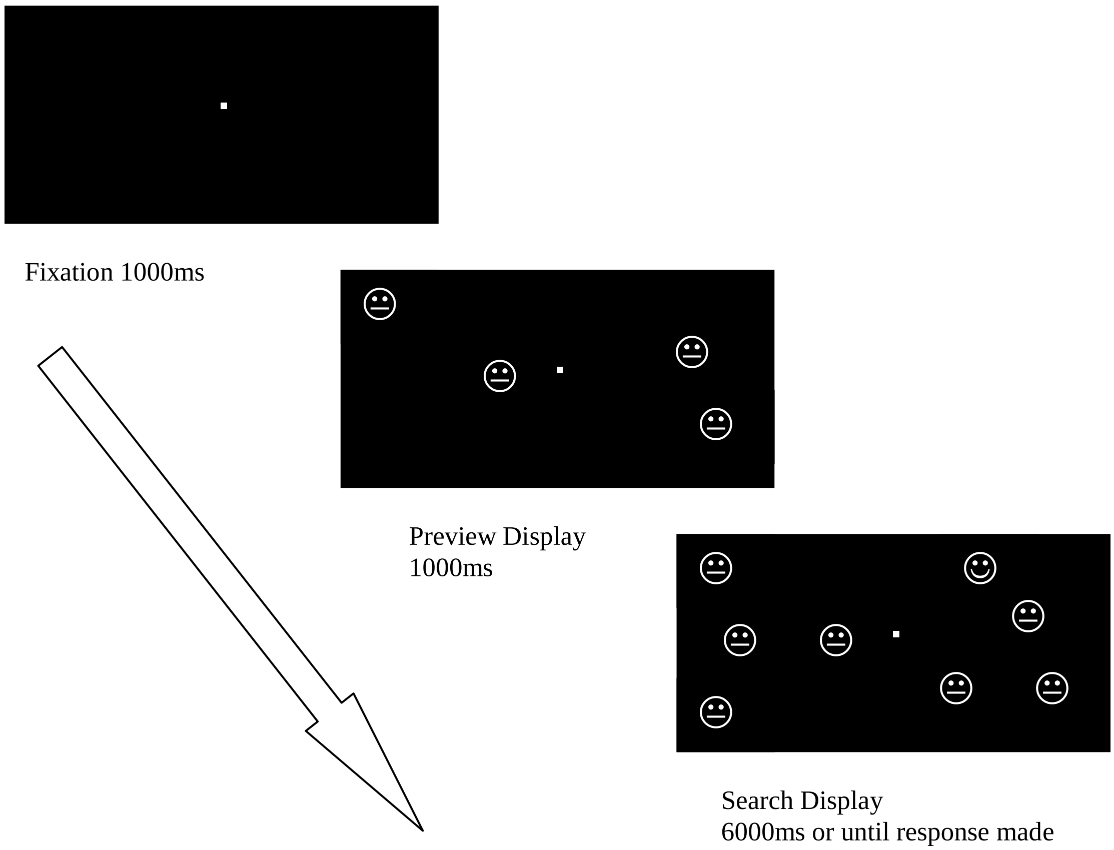


Figure 5.2 An example preview search trial with a positive face target and display size of 8 from Experiment 3.

In all conditions, the search display remained on screen until the participant responded or for 6000 ms, after which the next trial began. If an error was made, or no response was given when a target was presented, feedback was given in the form of a short tone (1000 Hz, 500 ms).

5.5 Results

5.5.1 *Reaction time data*

All anticipatory RTs (i.e. < 150 ms) were discarded and treated as errors. Mean correct RTs were then calculated for each cell of the design individually for each participant. Overall mean correct RTs are shown in Figures 5.3a and 5.3b, with search slopes statistics presented in Table 5.1[8]. As in previous research on the preview benefit, search slopes were plotted and calculated using the same display sizes as for the FEB. This procedure gives the values that would be expected if observers were able to fully ignore the old items in the preview condition, and enables direct comparison of the preview condition with both baseline conditions (i.e. HEB and FEB). An ANOVA was first conducted including all three conditions (HEB, FEB, Preview), in order to confirm that there was a difference in performance across the three versions of the search task.

Additional follow-up ANOVAs (comparing the Preview condition with the FEB and Preview condition with the HEB individually) were then conducted to determine the extent to which a preview benefit occurred. A full preview

[8] Consistent with previous visual attention research, performance is reported according to overall RT, search slope and intercept. Search slope and RT are evaluated further to provide the most complete assessment of performance differences (i.e. differences in search efficiency *and* RT, independently of set size). Intercept differences are not analysed in more detail (see Watson & Humphreys, 1998; for rationale).

benefit would be indicated if performance in the preview condition differed from the FEB, but not from the HEB. In contrast, no preview benefit would be indicated if the preview differed from the HEB, but not from the FEB (see Watson & Humphreys, 1997, for further details). Accordingly, full evaluation of performance in the preview condition was conducted via ANOVA for all search conditions followed by planned comparisons between conditions.

Table 5.1 Search slopes statistics for Experiment 3, by search condition and target valence

	Search Condition and Target Valence					
	HEB		FEB		Preview	
Slope Statistics	Negative	Positive	Negative	Positive	Negative	Positive
Slope (ms/item)	26.61	38.70	29.22	45.87	27.33	47.05
Intercept (ms)	514.37	525.58	640.54	710.24	548.06	512.83
R^2	0.99	0.99	0.99	0.98	0.99	1.00

5.5.2 *HEB vs. FEB vs. Preview Condition*

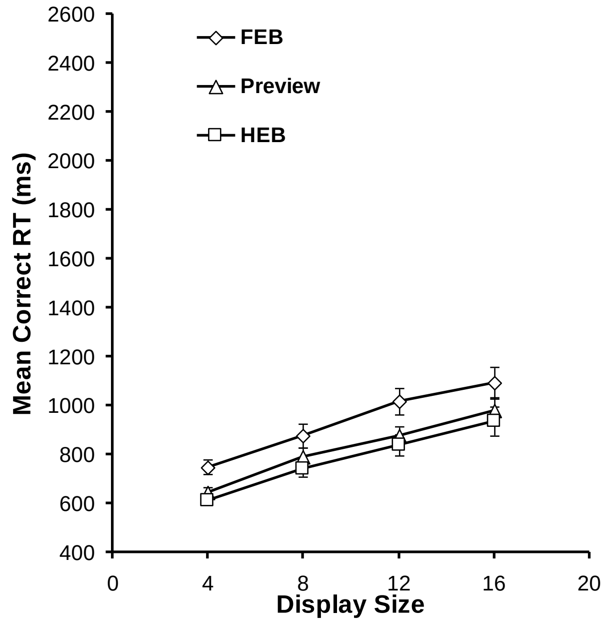
Mean correct RTs were analyzed using a 3 (condition) x 4 (display size) x 2 (target valence) within-subjects ANOVA. There were highly significant main effects of Condition, $F(2,34)=30.45$, $MSE= 52756.72$, $p<.001$, Display Size, $F(3,51)= 157.57$, $MSE= 23572.49$, $p<.001$, and Target Valence, $F(1,17)= 86.29$, *MSE*= 39107.67, *p*<.001. Overall RTs were longest in the FEB and shortest in the HEB, increased as display size increased, and were shorter for negative than for positive valence targets.

There were also significant Condition x Target, *F*(2,34)=9.57, *MSE*= 10795.76, *p*<.005, and Target x Display Size, *F*(3, 51)=27.71, *MSE*= 6801.93, *p*< .001 interactions, indicating that the overall effect of valence differed across condition (impairing search efficiency more when searching for a positive target in the FEB and Preview condition, compared with the HEB), and that display size had a smaller effect on negative valence targets than on positive valence targets (the search slopes for negative targets were shallower). Both the Condition x Display Size, and the Condition x Target x Display Size interaction, proved unreliable, both *F*s < 1.25, *ps* > 0.28.

5.5.3 *HEB vs. Preview Condition*

All three main effects were significant: RTs were faster overall in the HEB; Condition, *F*(1,17)=4.90, *MSE*= 45702.61, *p*<.05, increased with Display Size, *F*(3,51)= 139.06, *MSE*= 16920.13, *p*<.001, and negative targets were detected faster than positive, *F*(1,17)= 50.97, *MSE*= 25958.26, *p*<.001. The difference between positive and negative targets increased with Display Size, *F*(3,51)= 32.39, *MSE*= 3755.62, *p*<.001. However, no other interactions reached significance, all *Fs* < 2.12, *ps* > 0.16.

A) Negative targets amongst neutral distractors



B) Positive targets amongst neutral distractors

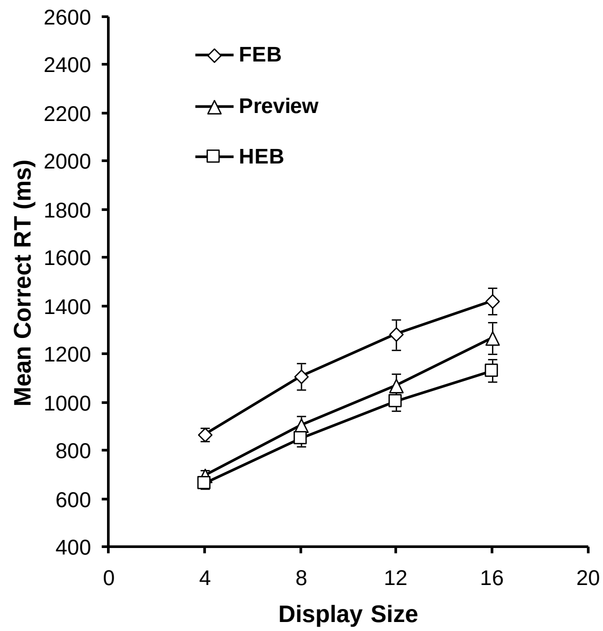


Figure 5.3 Mean correct RTs for detecting negative targets (Panel A) and positive Targets (Panel B) as a function of condition and display size for Experiment 3. Error bars indicate ±1 standard error.

5.5.4 *HEB vs. FEB*

All three main effects proved significant. RTs were shorter overall in the HEB than in the FEB, $F(1,17)=46.67$, $MSE= 64418.90$, $p<.001$, and were shorter for negative targets than positive, $F(1,17)= 84.61$, $MSE= 28863.57$, $p<.001$, and increased as Display Size increased, $F(3,51)= 119.81$, $MSE= 19933.36$, $p<.001$. There were also significant Target Valence x Display Size, $F(3, 51)=12.24$, $MSE= 8308.15$, $p< .001$, and Condition x Target, $F(1,17)= 14.12$, $MSE= 13802.56$, $p<.005$, interactions, with RTs increasing more steeply with increasing display size for positively valenced targets, and more in the FEB than the HEB. Both the Condition x Display Size, and the Condition x Target Valence x Display Size, interaction were not significant, both $Fs < 1.74$, $ps > .16$.

5.5.5 *FEB vs. Preview Condition*

All three main effects proved significant. RTs were faster in the Preview Condition than in the FEB, $F(1,17)=33.00$, $MSE= 48148.64$, $p<.001$, negative targets were detected more quickly than positive, $F(1,17)= 83.45$, $MSE= 34189.28$, $p<.001$ and RTs increased as Display Size increased, $F(3,51)= 143.03$, $MSE= 18866.17$, $p<.001$. There was also a significant Target x Display Size, $F(3, 51)=21.18$, $MSE= 7532.27$, $p< .001$, and Condition x Target interaction, $F(1,17)=9.01$, $MSE= 11015.17$, $p<.05$, indicating that, search was more efficient for the negative target and that the overall difference between positive and negative targets was greater in the FEB condition. Neither the Condition x Display Size, nor the Condition x Display Size x Target, interaction reached significance, both $Fs < 1$.

5.5.6 *Effects of valence in each condition*

In order to determine whether there was a negative target advantage in all conditions separate 2 (Target Valence) x 4 (Display Size) repeated measures ANOVAs were calculated for the HEB, FEB and Preview condition. This revealed that negative valenced targets were detected faster overall than positive targets in all three conditions, HEB, $F(1,17)= 40.58$, $MSE=15494.75$, $p<.001$, FEB, $F(1,17)= 73.91$, $MSE=27171.38$, $p<.001$, Preview condition, $F(1,17)= 52.35$, $MSE=18033.07$, $p<.001$. RTs also increased as display size increased, HEB, $F(3,51)=97.95$, $MSE=10518.63$, $p<.001$, *FEB*, F(3,51)=, $MSE=17156.84$, $p<.001$, Preview condition, $F(3,51)=102.27$, $MSE=13046.39$, $p<.001$. Finally, the Target Valence x Display size conditions were significant for all three conditions indicating that search slopes for negative targets were shallower (search rate was faster) for negative targets than for positive targets: HEB, $F(3,51)=9.27$, $MSE=7570.60$, $p<.001$, FEB, $F(3,51)=6.06$, $MSE=5924.48$, $p<.005$, Preview Condition, $F(3,51)=17.84$, $MSE=5291.26$, $p<.001$.

5.5.7 *Error data*

Mean percentage errors are shown in Table 5.2. On search trials, errors were low overall (1.75%) and were logarithmically transformed in order to avoid compression issues. These transformed data were then analyzed with a 3(Condition) x 4 (Display Size) x 2 (Target Valence) repeated measures ANOVA. There was a marginally significant main effect of Target Valence, $F(1,17)=4.15$, $MSE=0.16$, $p=.06$, with more errors made when searching for a positive target.

Table 5.2 Mean percentage error rates for Experiment 3, by search condition, target valence and display size

	Display Size				
	2	4	6	8	
Condition	4	8	12	16	Mean
HEB					
Negative Target	0.83	2.22	0.83	1.11	1.25
Positive Target	1.11	2.50	2.22	1.67	1.88
Catch Trials	20.83	6.94	6.94	5.56	10.07
FEB					
Negative Target	1.11	1.94	1.39	1.11	1.39
Positive Target	2.78	1.39	0.83	3.89	2.22
Catch Trials	11.11	11.11	4.17	5.56	7.99
Preview					
Negative Target	1.94	1.67	1.67	0.56	1.46
Positive Target	1.67	1.67	2.22	3.61	2.29
Catch Trials	18.06	13.89	4.17	4.17	10.07

There was also a significant Target Type x Display Size interaction, $F(3,51)=4.16$, $MSE= 0.09$, $p< .05$, indicating that errors increased more with Display Size for positive valence targets. No other main effects or their interaction reached significance, all $Fs < 1.45$, $ps > .20$.

Overall error rate on catch trials was 9.38%. These data were analyzed with a 3 (Condition) x 4 (Display Size) repeated measures ANOVA, and showed a significant main effect of Display Size, $F(3,51)=8.48$, $MSE=194.21$, $p<.001$. The main effect of Condition and the Condition x Display Size interaction, failed to reach significance, both Fs < 1.18, ps $> .32$.

5.6 Discussion

Experiment 3 aimed to explore the efficiency of preview search with facial stimuli. The first finding was that the typical negative face superiority effect was obtained (e.g., Eastwood et al., 2001; Fox et al., 2000) across all conditions, measured both in terms of overall RTs and search slopes. According to the inhibitory visual marking account of the preview benefit, ignoring old distractors requires the top-down commitment of attentional resources and is capacity limited (Watson & Humphreys, 1997). Thus, it might have been expected that the search advantage for negatively valenced stimuli would have been reduced in the preview search condition, due to the commitment of attentional resources elsewhere. However, this did not appear to be the case, in that there was a strong RT advantage for negative targets, even in the preview condition. This finding supports the notion that the detection of threat stimuli is mediated via a relatively low level or automatic set of processes (e.g., Vuilleumier et al., 2001, LeDoux, 1996; Hansen & Hansen, 1988; Öhman, 1993; Mogg & Bradley, 1999).

The second finding relates to whether a preview benefit would be obtained with facial stimuli. Typically, the preview benefit is indicated by both a reduction in search slope and overall RTs, relative to a FEB in which there is no opportunity to ignore any of the old items. Considering search slopes first, slopes in the preview condition did not differ from either baseline. Moreover, search slopes in the HEB and FEB were statistically equivalent. This suggests that detecting the target became relatively easier (reducing the search slope) as display size increased, most likely because as search displays became more crowded, the contrast between the odd-one-out target and the background distractors became more salient (e.g., Wolfe, Butcher, Lee & Hyle, 2003; Nothdurft, 2001; Bravo & Nakayama, 1992). Here, this effect would thus render the search slope measure unreliable in terms of indicating a preview benefit.

In contrast, based on the second measure of preview performance (overall RTs), responses in the preview condition were reliably faster than in the FEB, but slower than the HEB. This suggests that a partial, although not complete, preview benefit was obtained when trying to ignore face stimuli with a neutral expression (see Hodsoll & Humphreys, 2005, and Braithwaite, Humphreys & Hulleman, 2005, for previous assessments of the preview benefit based on overall RT differences). Thus, Experiment 3 provides initial evidence that faces might be more difficult to ignore over time than more abstract stimuli, perhaps due to their special status for human interactions.

In contrast to neutral faces, Experiments 5 and 6 will examine preview efficiency when ignoring valenced faces. However, examining this in the preview paradigm entails observers knowing the valence of the target face in advance, (as valence of the preview items will predict the valence of the target item). Conversely, the majority of the previous research on face-based valence effects in visual search has required participants to detect an odd-one-out target (e.g., Hansen & Hansen, 1988; Eastwood et al., 2001), without knowledge of the particular target-defining expression.

Moreover, Williams et al., (2005b) found a reversal of the standard search advantage for negatively valenced face targets, when participants were aware of the target's valence. Therefore, it is possible that the negative-superiority effect might be reduced, abolished or even reversed when the valence of the target is known in advance. Accordingly, to evaluate these effects for subsequent methodology, search efficiency for valenced targets was examined in Experiment 4, with and without top-down knowledge of the target valence, and using the same type of stimuli presented in Experiment 3.

5.7 Experiment 4: Comparison of visual search for valenced faces, with and without top-down knowledge of the target

Previous work demonstrating negative face superiority effects has predominantly used an "odd-one-out" paradigm (e.g., Hansen & Hansen, 1988; Hampton et al., 1994; Purcell et al., 1996; Eastwood et al., 2001), where the valence of the target was not known beforehand. However, Williams et al., (2005b) found a search advantage for happy face targets amongst neutral face distractors (in comparison with fearful face targets), when the target valence was known prior to search, although later work, (Williams, McGlone, Abbott & Mattingley, 2008) indicated no behavioral differentiation, nor any modulation of amygdalar activity according to top-down task demands (i.e. instructions to search for face of particular valence). Experiment 4 examined whether an equivalent advantage for negative face detection, as shown in Experiment 3, would hold when the valence of the target was known in advance.

Although many models of attentional control encompass mechanisms by which behavioral goals or attentional set interact with bottom-up stimulus property effects (e.g., Folk et al., 1992, 1994), it is unknown whether such top-down facilitation of target detection would add to valence-driven effects or reduce them. For example, the advantage gained by knowing the target identity might outweigh any automatically generated bottom-up advantage for negative stimuli. Similarly, repeating only a negative target throughout a block of trials might increase habituation to the stimulus, to the point it is no longer perceived as a threat. This behavioral effect would mirror the rapid amygdalar habituation to valenced facial stimuli seen in neuroimaging studies (e.g., Wright et al., 2001; Breiter et al., 1996; Morris et al., 1996; see also Carretie, Hinojosa, & Mercado, 2003, for ERP data on neural habituation to emotional stimuli).

Thus, in Experiment 4, participants performed in two conditions. In one condition, the target valence remained fixed throughout a block, and so they had prior knowledge of the target identity on every trial (i.e. either a positive or negative face). In this condition, they could potentially use valence-based top-down knowledge in order to guide their search to the target. In the other condition, targets were mixed within the block, so that participants had no foreknowledge of the target on a trial-by-trial basis, and guidance by valence was not possible. Thus, this condition was equivalent to the HEB and FEB of Experiment 3, in which the target was the “odd-one-out”, and showed a strong negative target advantage.

5.8 Method

5.8.1 *Participants*

Twelve students at the University of Warwick (8 female, 4 male) participated for course credit. Participants were aged between 18 and 37 years (*M*=21.50 years) and 11 were right handed. All participants self-reported normal or corrected to normal vision.

5.8.2 *Stimuli and Apparatus*

Stimuli and apparatus were identical to that in Experiment 3, with the exception of display sizes, which were 6, 8 and 10 (three display sizes were used in this experiment in order to keep the total number of trials similar to those of the following preview experiments).

5.8.3 *Design and Procedure*

The experiment was based on a 3 x 2 x 2 within-participant design (Display Size x Block Type x Target Valence). Each block (negative target, positive target, mixed negative/positive target) comprised 120 experimental trials and a further 12 catch trials, where no target was present. Where a target was presented, it appeared to the right of the screen for half of the trials, with the remainder presented on the left side. Each participant completed four blocks of trials (one positive target, one negative target and two mixed target blocks). The order of block type and target valence was counterbalanced, with alternating mixed and single target blocks. Participants were instructed to locate the “odd-one-out” in a mixed target block, and to detect the negative or positive face, according to whichever single target block was being presented.

5.9 Results

5.9.1 *Reaction time data*

All anticipatory RTs (i.e. < 150 ms) were discarded and treated as errors. Mean correct RTs are shown in Figure 5.4 and search slope statistics in Table 5.3. Overall, search was more efficient for negative targets, with no clear advantage for single valence target or mixed valence target blocks. A 3 (Display size) x 2 (Target valence) x 2 (Block type) repeated-measures ANOVA showed that negative targets were detected faster than positive, $F(1,11)=118.54$, $MSE = 16789.24$, $p<.001$, and RTs increased as display size increased, $F(2,22)=83.31$, $MSE=4534.23$, $p<.001$. However, there was no significant effect of Block type, $F < 1$.

In addition, there was a significant Target x Display size interaction, $F(2,22)=11.72$, $MSE = 2635.58$, $p<.001$, showing that search slopes were shallower for negative targets than for positive targets. Importantly, neither the Block type x Display size, $F < 1$, Block x Target valence, $F(1,11) = 3.43$, $MSE= 12695.38$, $p= .09$, interactions, nor the 3-way interaction, $F < 1$ reached significance. Thus, the negative target advantage did not differ between mixed and single valence blocks of trials.

Table 5.3 Search slope statistics for Experiment 4, by search condition and target valence

	Block Type and Target Valence			
	Single Target		Mixed Target	
Slope Statistics	Negative	Positive	Negative	Positive
Slope (ms/item)	29.62	59.22	33.50	53.48
Intercept (ms)	628.34	661.46	639.12	679.65
R^2	0.99	0.96	0.99	0.99

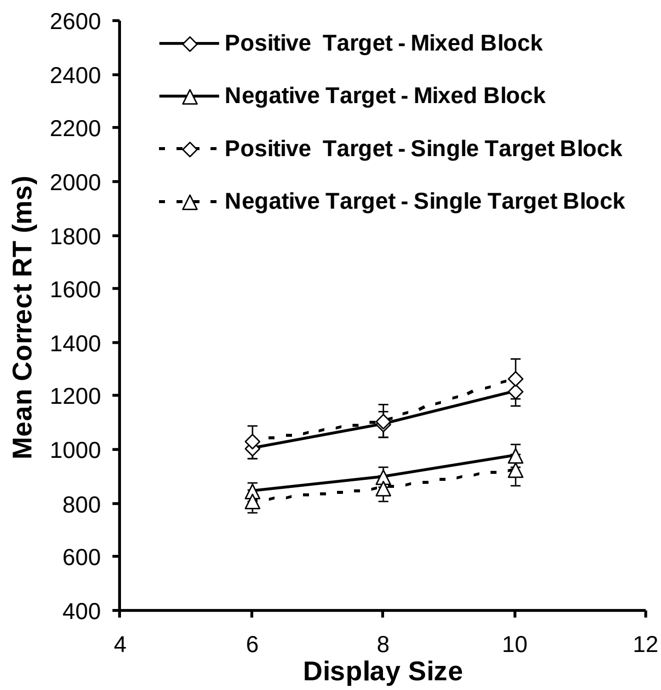


Figure 5.4 Mean correct RTs for detecting positive and negative targets, as a function of condition and display size for Experiment 4. Error bars indicate ±1 standard error.

5.9.2 *Error data*

Mean percentage errors rates are shown in Table 5.4. Error rates on search trials were low overall (1.48 %) and were logarithmically transformed, as in Experiment 3. These data were subjected to a 3 (Display Size) x 2 (Target) x 2 (Block type) repeated-measures ANOVA. There was a significant main effect of Target, $F(1,11)= 11.47$, $MSE= 0.03$, $p<.05$, with errors more frequent in trials with a positive target.

Table 5.4 Mean percentage error rates for Experiment 4, by block type, target valence and display size

	Display Size			
Block Type	6	8	10	Mean
Single Target				
Negative Target	0.21	1.04	0.42	0.56
Positive Target	0.83	0.42	0.63	0.63
Catch Trials	4.17	1.04	3.13	2.78
Mixed Target				
Negative Target	1.04	1.25	1.04	1.11
Positive Target	1.67	1.25	1.25	1.39
Catch Trials	6.25	2.08	3.13	3.82

No other main effects or their interaction approached significance, all *Fs* < 1.89, *ps* > .17. The overall error rate on catch trials was 3.3% and was analyzed with a 2 (Block type) x 3 (Display Size) ANOVA. No main effects or their interaction approached significance, all *Fs* < 1.79, all *ps* > 0.19.

5.10 Discussion

The main purpose of Experiment 4 was to establish whether a negative superiority effect would remain when observers knew the valence of the target on every trial (as is the case in the following experiments). One possibility is that top-down knowledge might have outweighed any automatic stimulus-driven negative advantage, particularly given the enhanced detection of happy faces found by Williams et al., (2005b), when target identity was known beforehand by participants. Another is that the repetition of a negative stimulus may have led to neural and possibly behavioral habituation.

Clearly this was not the case, with a negative target advantage evident in the single block conditions, both in terms of overall RTs and search slopes. Indeed, numerically, there was a greater difference in search slopes in the blocked conditions than in the mixed condition. The finding that top-down knowledge neither helped nor hindered search for negative valenced targets is consistent with the negative superiority effect being based on a relatively automatic or low level processing advantage (e.g., Vuilleumier et al., 2001, LeDoux, 1996, 1998; Hansen & Hansen, 1988; Öhman, 1993; Mogg & Bradley, 1999).

5.11 Experiment 5: Ignoring positive faces

Experiment 3 established that a robust, albeit partial, preview benefit emerged when the task was to ignore neutral faces and detect a valenced face amongst additional neutral faces. In Experiment 5, we determine whether positively valenced faces can also be effectively ignored. As we are assessing the effects of stimuli presented in the preview, this necessarily entails focusing on the ability to ignore valenced preview distractors, rather than the ability to detect a valenced target. Several results are possible here. If positive faces are evaluated as being non-threatening, and therefore, are relatively ineffective at capturing and holding attention, then we would expect to obtain a robust preview benefit. Indeed, if the ability to ignore old distractors increases as they become less negative, then we might expect a stronger preview benefit than in Experiment 3 (if we accept that positive faces are less negative than neutral faces). Alternatively, if any kind of emotional expression (positive or negative) tends to draw attention, according to a *general emotionality effect* (e.g., Fox et al., 2000; Martin, Williams & Clark; 1991), then the preview benefit might be reduced further, relative to ignoring neutral expression distractors.

5.12 Method

5.12.1 *Participants*

Twelve students at the University of Warwick (7 female, 5 male) participated in this study for payment or course credit. Participants were aged between 19 and 27 years (*M*=23.33 years), and ten of these were right handed. All other participants self-reported normal or corrected to normal vision.

5.12.2 *Stimuli and Apparatus*

Stimuli and apparatus were identical to those in Experiment 3, except that target stimuli were always negative faces. In the preview condition, 2, 4, 6 or 8 positive faces were presented for 1000ms followed by 2, 4, 6 or 8 (respectively) neutral face distractors, with the target negative face taking the place of one of the distractors on non-catch trials. Thus, the final full preview search array consisted of a negative target (when present) amongst neutral and positive face distractors. The FEB was the same, except that all the items appeared simultaneously. In the HEB, only the second set of items from the preview condition was presented.

5.12.3 *Design and Procedure*

The experiment was based on a blocked 3 (condition: Preview, FEB, HEB) x 3 (Display size) within-subjects design. Each search condition block (HEB, FEB and Preview) comprised 160 experimental trials and a further 16 catch trials, where no target was present. As in Experiment 3, when a target was presented, it was shown either to the right or left side of the screen with participants indicating target location, see Figure 5.5 for an example preview trial.

5.13 Results

5.13.1 *Reaction time data*

Mean correct RTs are shown in Figure 5.6 and search slope statistics in Table 5.5. Search slope statistics were calculated in the same way as in Experiment 3, as was evaluation of Preview Benefit, relative to both baseline conditions.

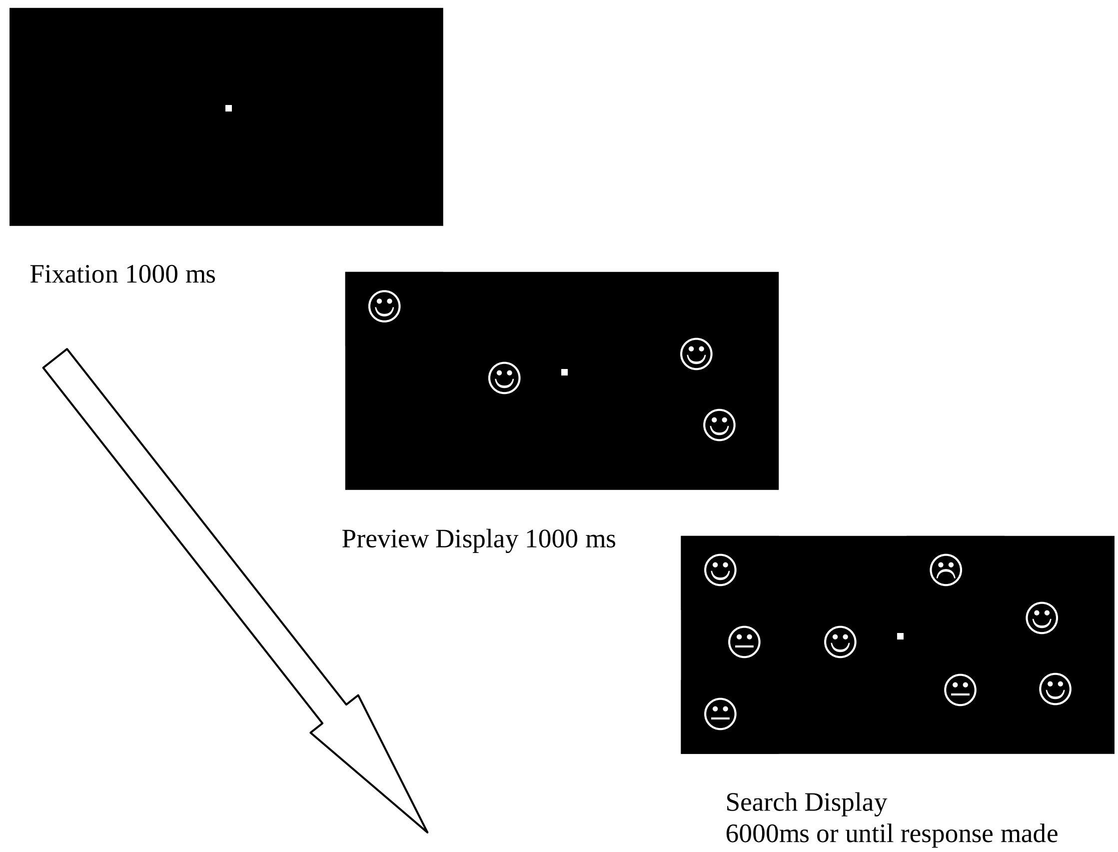


Figure 5.5 An example preview search trial with a negative target and positive preview distractors from Experiment 5

Similarly to Experiment 3, search was most efficient in the HEB, and least efficient in the FEB.

5.13.2 *HEB vs. FEB vs. Preview Condition*

Search data were subjected to an initial 3 x 4 repeated-measures ANOVA, where significant main effects of both Search Condition, $F(2,22)=40.14$, $MSE= 39113.89$, $p<.001$, and Display Size, $F(3,33)=70.18$, $MSE= 12466.38$, $p<.001$, were found. Faster responses were produced in the HE baseline and Preview conditions than in FE baseline and overall, RTs increased as Display size increased. However, there was a significant Condition x Display Size interaction, $F(6,66)= 9.30$, $MSE= 4993.21$, $p < .001$, showing that search efficiency differed across conditions.

5.13.3 *HEB vs. FEB*

RTs were overall shorter in the HEB than in the FEB, $F(1,11)=51.26$, $MSE= 55335.62$, $p<.001$ and increased with Display Size, $F(3,33)=55.22$, $MSE = 11176.34$, $p<.001$. In addition, RTs increased more with Display Size in the FEB than the HEB, $F(3,33)=13.61$, $MSE= 6642.97$, $p<.001$, with search slopes shallower in the HEB than in the FEB.

5.13.4 *HEB vs. Preview Condition*

RTs were shorter overall in the HEB than in the Preview condition, $F(1,11)= 12.70$, $MSE= 10490.50$, $p<.005$, and also increased with Display Size, $F(3,33)=64.18$, $MSE= 5737.06$, $p<.001$. Of most interest was a significant

Table 5.5 Search slope statistics for Experiment 5, for detecting negative targets amongst positive and neutral distractors, by search condition

	Search Condition		
Slope Statistics	HEB	FEB	Preview
Slope (ms/item)	19.29	42.75	28.43
Intercept (ms)	476.62	585.85	459.76
R^2	0.97	1.00	0.99

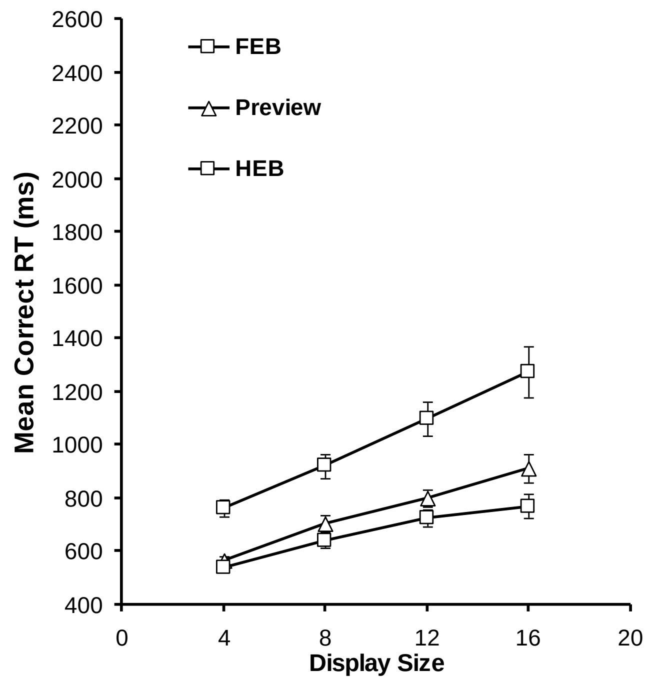


Figure 5.6 Mean correct RTs for ignoring positive distractors, as a function of condition and display size for Experiment 5. Error bars indicate ±1 standard error.

Condition x Display Size interaction, $F(3,33)=10.00$, $MSE= 1446.59$, $p<.001$, showing that search slopes were greater in the preview condition.

5.13.5 *FEB vs. Preview Condition*

RTs were shorter overall in the Preview Condition, $F(1,11)=33.78$, $MSE= 51515.55$, $p<.001$, and increased with Display Size, $F(3,33)=62.32$, $MSE= 13012.56$, $p<.001$. In addition, search slopes were shallower in the preview condition than in the FEB, $F(3,33)=4.99$, $MSE= 6890.06$, $p<.05$.

5.13.6 *Error data*

Mean percentage errors are shown in Table 5.6. Errors rates in search trials remained low overall (0.99 %), and were subjected to similar logarithmic transformation as in Experiments 3 and 4. These transformed data differed across conditions, $F(2,22)= 6.21$, $MSE= 0.07$, $p<.05$, and increased as Display size increased, $F(3,33) = 3.46$, $MSE= 0.05$, $p<.05$. There were also some non-systematic differences across conditions as a function of display size, as revealed by a significant Condition x Display Size interaction, $F(6,66)= 5.24$, $MSE=0.05$, $p<.001$.

Overall error rate on catch trials was 5.56%. The data were analyzed with a 3 (Condition) x 4 (Display Size) repeated-measures ANOVA, and showed a significant main effect of Display Size, $F(3,33)=5.50$, $MSE=98.91$, $p<.005$. The effect of Condition and the Condition x display size interaction did not approach significance, both Fs < 1.

Table 5.6 Mean percentage error rates for Experiment 5, by search condition and display size

	Display Size				
	2	4	6	8	
	4	8	12	16	Mean
Search trials					
HEB	1.04	1.88	1.25	0.83	1.25
FEB	1.25	0.21	0.83	2.92	1.30
Preview	0.00	0.21	0.42	1.04	0.42
Catch Trials					
HEB	10.42	2.08	2.08	4.17	4.69
FEB	12.50	4.17	8.33	0.00	6.25
Preview	10.42	8.33	2.08	2.08	5.73

5.14 Discussion

Experiment 5 examined the efficiency of ignoring faces showing positive affect. One potential outcome was that the preview search would be equally, or more efficient than when ignoring neutral faces (as in Experiment 3), if the ability of a stimulus to capture and hold attention decreases as positive affect increases. Another possibility was that ignoring positive faces would be relatively difficult if emotional affect, either positive or negative, was effective at capturing and holding attention. Overall, the results showed that, as in Experiment 3, a robust preview benefit was obtained. In this case, the benefit was observed in terms of both overall RTs and search slopes (note that a robust search slope difference between the FEB and HEB was demonstrated here). However, as in Experiment 3, a full preview benefit was not obtained, with the overall RTs and search slopes remaining higher in the preview condition than in the HEB. Thus, similar to our finding with neutral stimuli, previewing positive affect faces produced a partial preview benefit. In Experiment 6, the efficiency of ignoring negative old stimuli is investigated.

5.15 Experiment 6: Ignoring negative faces

In Experiment 5, the efficiency of ignoring negative valenced faces was examined. Given the previously demonstrated ability of negative faces to attract and hold attention (e.g., Lavie et al., 2003; Fox et al., 2000, 2001, 2002; Georgiou et al., 2005), we might expect that it would be particularly difficult to ignore them during time-based visual search tasks, leading to a greatly reduced or abolished preview benefit. Accordingly, in the preview condition of Experiment 6, observers were given a preview of negative faces, after which an additional set of neutral faces and a positive target (when present) was added.

5.16 Method

5.16.1 *Participants*

Thirteen students at the University of Warwick (8 female, 5 male) participated for payment or course credit. All were aged between 18 and 26 years (*M*=20.31 years), and ten were right handed. One participant was excluded due to visual defects that were likely to have compromised performance. All other participants self-reported normal or corrected to normal vision.

5.16.2 *Stimuli and Apparatus*

Stimuli and apparatus were identical to that of Experiment 3, except that the preview display comprised negative faces, and the target was positively valenced.

5.16.3 *Design and Procedure*

The design and procedure were the same as in Experiment 5.

5.17 Results

5.17.1 *Reaction time data*

All anticipatory RTs (i.e.< 150 ms) were discarded and treated as errors. Mean correct RTs are shown in Figure 5.7 and search slopes statistics are shown in Table 5.7. Search slope statistics and assessment of preview benefit (relative to baseline conditions) were calculated in the same way as in Experiments 3 and 5 above. Similarly to Experiment 5, search was most efficient in the HEB, and least efficient in the FEB.

5.17.2 *HEB vs. FEB vs. Preview Condition*

Search data were subjected to an initial 3x4 repeated-measures ANOVA, with significant main effects of Search Condition, $F(2,22)=44.08$, $MSE= 135530.74$, $p<.001$, and Display Size, $F(3,33)=309.59$, $MSE = 13364.35$, $p<.001$. Faster responses were produced in HEB and Preview Conditions than in FEB, with RTs increasing as Display Size increased. In addition, there was a significant Condition x Display Size interaction, $F(6,66)=11.18$, $MSE= 18629.07$, $p<.001$, indicating that search efficiency differed across conditions.

5.17.3 *HEB vs. FEB*

RTs were faster overall in the HEB, $F(1,11)=64.87$, $MSE= 169464.02$, $p<.001$, and increased with Display Size, $F(3,33)=177.24$, $MSE= 15299.87$, $p<.001$. The Condition x Display Size interaction, $F(3,33)=22.80$, $MSE= 17254.96$, $p<.001$ was also significant, indicating that the search slope was shallower in the HEB.

5.17.4 *HEB vs. Preview Condition*

RTs were faster in the HEB than in Preview Condition, $F(1,11)=16.38$, $MSE= 40161.99$, $p<.005$, increased as Display Size increased, $F(3,33)=125.87$, $MSE= 14779.38$, $p<.001$, and the search slope in the HEB was shallower than in the Preview Condition, $F(3,33)=14.04$, $MSE = 8551.34$, $p<.001$.

Table 5.7 Search slope statistics for Experiment 6, for detecting positive targets amongst negative and neutral distractors, by search condition

	Search Condition		
Slope Statistics	HEB	FEB	Preview
Slope (ms/item)	40.56	89.10	67.14
Intercept (ms)	532.14	723.57.	431.89
R^2	0.99	0.99	1.00

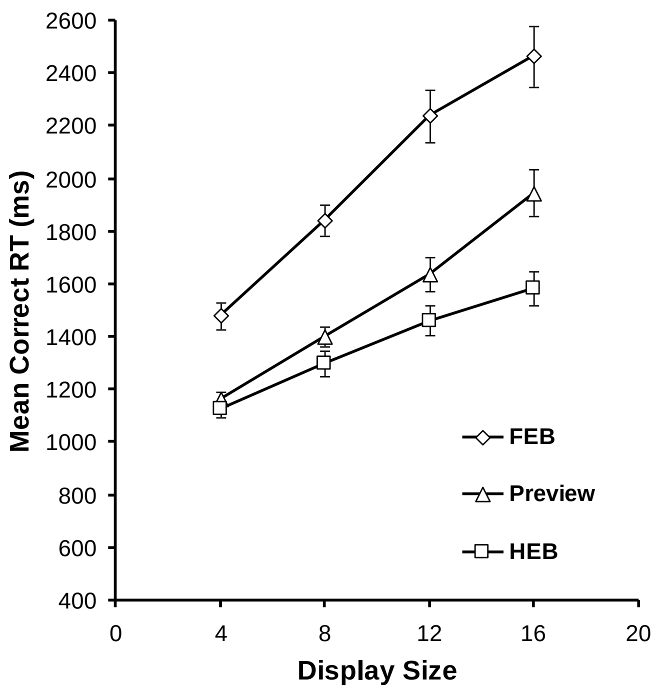


Figure 5.7 Mean correct RTs for ignoring negative distractors, as a function of condition and display size for Experiment 6. Error bars indicate ±1 standard error.

5.17.5 *FEB vs. Preview Condition*

RTs were faster in the Preview Condition than FEB $F(1,11)=31.85$, $MSE=196966.21$, $p<.001$, and increased with Display Size, $F(3,33)=255.99$, $MSE=15278.52$, $p<.001$. Of particular interest was a significant Condition x Display Size interaction, $F(3,33)=3.69$, $MSE= 30080.90$, $p<.05$, indicating that the preview search slope was shallower than the FEB slope.

5.17.6 *Error data*

Error data can be seen in Table 5.8. Overall, errors rates remained low on search trials (1.18%), and were logarithmically transformed before analysis. The transformed error rates increased as display size increased, $F(3,33) = 8.82$, $MSE=0.08$, $p<.001$ However, there were no significant differences across conditions, $F(2,22)= 2.43$, $MSE=0.14$, $p=.11$, nor was there a significant Condition x Display Size interaction, $F<1$. The overall error rate on catch trials was 4.86% and showed a significant main effect of Condition, $F(2,22)=3.96$, $MSE=80.10$, $p<.05$. The main effect of Display Size and the Condition x DS interaction were not significant, both *Fs* < 2.21, *ps* > .10.

5.18 Discussion

Experiment 6 examined the efficiency of ignoring negative faces, presented as a preview. Given previous findings that negative faces can be particularly effective in capturing and holding attention, one might have expected that the preview benefit would have been greatly weakened or abolished completely, in comparison to when neutral (Experiment 3) or positive (Experiment 5) faces had to be ignored. However in contrast (and as in Experiments 3 and 5), a robust (albeit partial) preview benefit for ignoring negative faces was obtained, measured both in terms of overall RTs and search slopes. Thus, the present experiment provides a rare example of when negative faces do not seem to hold a special status for the visual attention system (see also Pessoa et al., 2002; Holmes et al., 2003, *but* cf. Fox et al., 2002; Georgiou et al., 2005; Eastwood et al., 2001; Hansen & Hansen, 1988; Hampton et al., 1989). This will be explored further in Experiments 8 and 9.

Table 5.8 Mean percentage error rates for Experiment 6, by search condition and display size.

	Display Size				
	2	4	6	8	
	4	8	12	16	Mean
Search Trials					
HEB	0.42	0.21	0.42	1.67	0.68
FEB	0.83	1.04	1.67	2.71	1.56
Preview	0.21	1.04	0.83	3.13	1.30
Catch Trials					
HEB	8.33	12.50	2.08	8.33	7.81
FEB	6.25	4.17	2.08	0.00	3.13
Preview	6.25	6.25	2.08	0.00	3.65

However, it should be noted that, although Experiments 5 and 6 show that a robust preview benefit can be obtained with both positive and negative old distractors, it is difficult to determine whether there is any quantifiable difference between ignoring positive and negative faces with the current form of analysis. A simple between-experiment comparison is complicated by the fact that the baseline search slopes differ between experiments, due to the overall effect of target valence on search efficiency, even in standard visual search conditions.

Accordingly, measures of preview search efficiency (PE) were calculated, that were independent of the overall baseline search rates. Two measures of preview search efficiency were calculated, one based on overall RTs ($PE_{overall}$) (1), and the other based on search slopes (PE_{slope}) (2). These measures were determined by calculating the difference between the FEB and preview search conditions, divided by the difference between the FEB and HEB search conditions for each individual participant[9], for both Experiments 5 and 6 (see Herrero, Crawley, van Leeuwen, & Raffone, 2007; for an earlier use of a similar procedure).

$$PE_{overall} = \frac{FEB_{overall} - PRE_{overall}}{FEB_{overall} - HEB_{overall}} \qquad (1)$$

$$PE_{slope} = \frac{FEB_{slope} - PRE_{slope}}{FEB_{slope} - HEB_{slope}} \qquad (2)$$

[9] In instances where the HEB value exceeded that of the FEB, that case was excluded from the analysis.

Calculated this way, as preview search becomes more efficient, PE tends towards 1, and as it becomes less efficient, it tends towards 0, with calculations bounded by 0 and 1. This analysis showed that the preview benefit was numerically larger for ignoring positive faces than for negative faces, in both RT ($PE_{positive}$ =0.75 ; $PE_{negative}$=0.70) and search slope analyses ($PE_{positive}$ = 0.61; $PE_{negative}$=0.46). However, this difference did not approach significance for either overall RTs, $t(22)= 0.47$, $p=.64$, or search slopes, $t(21)= 0.92$, $p = .37$. Nonetheless, in order to provide a stronger test of any differences between ignoring positive and negative faces, Experiments 5 and 6 were replicated, using a more powerful within-subjects design.

5.19 Experiment 7:

Replication of Experiments 5 and 6 using a within-participants design[10]

Experiment 7 replicated Experiments 5 and 6 using a within-subjects design, to provide a more robust test of any potential differences in the ability to ignore positive and negative faces. In addition to using a within-subjects design, we also doubled the number of participants in order to increase power.

5.20 Method

5.20.1 *Participants*

Twenty four students at the University of Warwick (15 female, 9 male) participated in this study for payment. Participants were aged between 18 and 30

[10] I would like to acknowledge the kind assistance of Cherelle McDonald in collecting the data in this experiment.

years (*M*=20 years), and 20 were right handed. All other participants self-reported normal or corrected to normal vision.

5.20.2 *Stimuli and Apparatus*

Stimuli and apparatus were identical to those for Experiments 5 and 6.

5.20.3 *Design and Procedure*

Experiment 7 was identical in design and procedure to Experiments 5 and 6. Half the participants completed three blocks of trials associated with ignoring negative faces (i.e. HEB, FEB, Preview), followed by the blocks associated with ignoring positive faces (i.e. HEB, FEB, Preview), presented in the same order. For the remaining participants, this order was reversed. In addition, block order (i.e. HEB, FEB, Preview) was counterbalanced across participants. A short practice block was presented directly before each full block of trials.

5.21 Results

5.21.1 *Overall reaction time data*

All anticipatory RTs (i.e.< 150 ms) were discarded and treated as errors. Mean correct RTs are shown in Figures 5.8a and 5.8b, and search slopes statistics in Table 5.9. First, the data were assessed as to whether the basic findings from Experiment 5 and 6 were replicated, by comparing search in the preview conditions with their respective baselines.

5.21.2 *Ignoring positive faces: Reaction time data*

5.21.2.1 *HEB vs. FEB vs. Preview Condition*

Search data were subjected to an initial 3 x 4 repeated-measures ANOVA, with significant main effects of Search Condition, $F(2,46)=85.24$, $MSE= 66207.73$, $p<.001$, and Display Size, $F(3,69)= 111.71$, $MSE = 19834.07$, $p<.001$. Faster responses were produced in HEB and Preview Conditions than in FEB, with RTs increasing as Display Size increased. In addition, there was a significant Condition x Display Size interaction, $F(6,138)=22.40$, $MSE= 6494.41$, $p<.001$, indicating that search slopes differed across conditions.

5.21.2.2 *HEB vs. FEB*

RTs were faster overall in the HEB, $F(1,23)=123.87$, $MSE= 85256.63$, $p<.001$, and increased with Display size, $F(3,69)=100.37$, $MSE= 14333.43$, $p<.001$. The Condition x Display Size interaction, $F(3,69)=30.76$, $MSE= 9316.28$, $p<.001$ was also significant, indicating a shallower search slope in the HEB condition.

Table 5.9 Search slope statistics for Experiment 7, by search condition and preview distractor valence

Ignoring positive faces			
	Search Condition		
Slope Statistics	HEB	FEB	Preview
Slope (ms/item)	18.43	48.35	35.03
Intercept (ms)	521.18	691.02	484.08
R^2	0.97	1.00	1.00

Ignoring negative faces			
	Search Condition		
	HEB	FEB	Preview
Slope (ms/item)	36.75	88.00	58.93
Intercept (ms)	535.67	770.98	451.15
R^2	0.98	0.99	1.00

5.21.2.3 *HEB vs. Preview Condition*

RTs were faster in the HEB, than in the Preview condition, *F*(1,23)=19.21, *MSE*= 40908.09, p<.001, and also increased as Display Size increased, *F*(3,69)=113.19, *MSE*= 8084.19, *p*<.001. Of most importance, the search slope in the HEB was shallower, as demonstrated by a significant Condition x Display Size interaction, *F*(3,69)=25.43, *MSE* = 3538.65, *p*<.001 .

5.21.2.4 *FEB vs. Preview Condition*

RTs were faster in the Preview Condition than the FEB, *F*(1,23)=77.07, *MSE*= 72458.48, *p*<.001, and increased with Display Size, *F*(3,69)=93.63, *MSE*=23744.94, *p*<.001. There was also a significant Condition x Display Size interaction, *F*(3,69)=9.03, *MSE*= 6628.31, *p*<.001, indicating a shallower search slope for the Preview condition than for the FEB.

5.21.3 *Error data*

All error data can be seen in Table 5.10. Overall, errors rates remained low in search trials (1.07%), and were according log transformed as described above. These data differed across conditions, *F*(2,46)= 3.87, *MSE*=0.07, *p*<.05, with more errors made in the FEB and increasing more with Display size in the FEB condition, *F*(6,138)= 3.08, *MSE*=0.06 , *p*<.05. The main effect of Display Size, did not approach significance, *F* < 1. The overall error rate on catch trials was 5.47%, and increased with Display Size, *F*(3,69)= 9.02, *MSE*= 103.57, *p*<.001.

However, the main effect of Condition and the Condition x Display Size interaction did not approach significance, both *Fs* < 1.23, both *ps* $> .29$.

5.21.4 *Ignoring negative faces: Reaction time data*

5.21.4.1 *HEB vs. FEB vs. Preview Condition*

Search data were subjected to an initial 3x4 repeated-measures ANOVA, with significant main effects of Search Condition, $F(2,46)=149.67$, $MSE= 101701.84$, $p<.001$, and Display Size, $F(3,69)= 285.52$, $MSE = 25370.08$, $p<.001$. Faster responses were produced in HEB and Preview Conditions than in FEB, with RTs increasing as Display Size increased. In addition, there was a significant Condition x Display Size interaction, $F(6,138)=39.16$, $MSE= 11202.99$, $p<.001$, indicating that search efficiency differed across conditions.

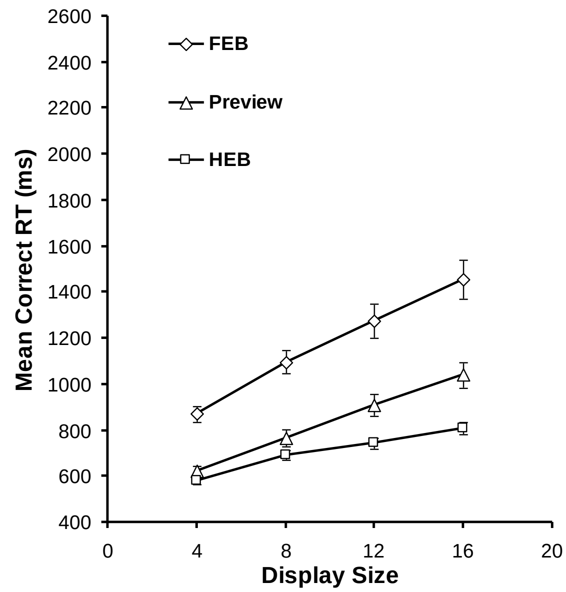
5.21.4.2 *HEB vs. FEB*

RTs were faster overall in the HEB, $F(1,23)=206.67$, $MSE= 129861.14$, $p<.001$, and increased with Display Size, $F(3,69)=234.01$, $MSE= 21564.03$, $p<.001$. The Condition x Display Size interaction, $F(3,69)=69.80$, $MSE= 12149.17$, $p<.001$ was also significant, indicating a shallower search slope in the HEB condition.

5.21.4.3 *HEB vs. Preview Condition*

Similarly, RTs were faster in the HEB, than in the Preview condition, $F(1,23)=29.30$, $MSE= 30852.71$, $p<.001$), and also increased as

A) Ignoring positive faces



B) Ignoring negative faces

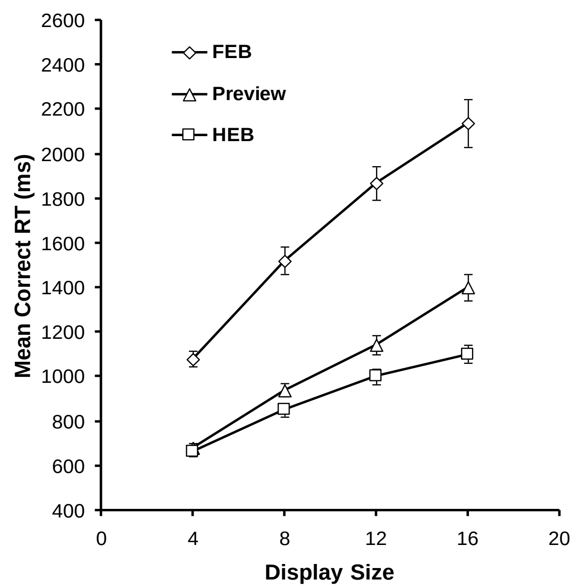


Figure 5.8 Mean correct RTs for ignoring positive distractors (Panel A) or negative distractors (Panel B) as a function of condition and display size for Experiment 7. Error bars indicate ±1 standard error.

Display Size increased, $F(3,69)=245.25$, $MSE= 22825.56$, $p<.001$. A significant Condition x Display Size interaction, $F(3,69)=25.63$, $MSE = 6523.72$, $p<.001$, indicated that the HEB search slope was shallower than the Preview slope.

5.21.4.4 *FEB vs. Preview Condition*

RTs were faster in the Preview Condition than the FEB, $F(1,23)= 123.91$, $MSE= 144391.66$, $p<.001$, and increased with Display Size, $F(3,69)=244.44$, $MSE=28395.64$, $p<.001$. A significant Condition x Display Size interaction, $F(3,69)=20.14$, $MSE= 14936.10$, $p<.001$, also indicated a shallower search slope for the Preview condition than for the FEB.

5.21.5 *Error data*

Mean percentage errors are shown in Table 5.10. Error rates were low overall (1.85%), and were transformed as described above. The transformed error rates increased as Display Size increased, $F(3,69) = 8.11$, $MSE= 0.09$, $p<.001$. In addition, there were significant differences across conditions, $F(2,46)= 16.18$, $MSE= 0.11$, $p<.001$, with higher error rates in the FEB and Preview conditions. A marginally significant Condition x Display Size interaction, $F(6,138)= 2.02$, $MSE= 0.08$, $p=.07$, was also evident.

The overall error rate on catch trials was 5.99%, and showed significant main effects of Condition, $F(2,46)=4.76$ $MSE=182.01$, $p<.05$, and Display Size, $F(3,69)= 11.52$, $MSE= 146.34$, $p<.001$, with errors increasing with display size, and a higher error rate reflected in the HEB. The Condition x Display Size interaction, $F(6,138)=2.41$, $MSE= 125.02$, $p <.05$, also proved significant.

5.22 Comparing preview search efficiency for ignoring positive and negative faces

Similarly to Experiments 5 and 6 above, a preview efficiency analysis was conducted on the data to quantify the numerical strength of the preview benefit. This analysis replicated the findings of the previous analysis, in that similar trends emerged for ignoring both valences (i.e., a partial preview benefit was demonstrated in both cases), and that PE indices were similar. However, in this instance, the numerical strength of the effect reversed, with the preview benefit larger for ignoring negative faces than for positive faces, in both RT ($PE_{positive} =0.70$; $PE_{negative}=0.79$) and search slope analyses ($PE_{positive} = 0.48$; $PE_{negative}=0.54$). This difference did not approach significance in either RT analyses, $t(46)=1.23$, $p= .22$, or search slopes, $t(45)= 0.69$, $p=.49$.

Table 5.10 Mean percentage error rates for Experiment 7, by search condition, target valence and display size

	Display Size				
	2	4	6	8	
	4	8	12	16	Mean
Search Trials					
Ignoring Positive					
HEB	1.25	0.73	0.73	0.73	0.86
FEB	0.42	1.46	2.50	1.77	1.54
Preview	0.83	0.42	1.04	0.94	0.81
Ignoring Negative					
HEB	0.83	0.73	0.83	1.04	0.86
FEB	1.88	1.98	2.40	5.30	2.89
Preview	1.56	1.25	1.98	2.40	1.80
Catch Trials					
Ignoring Positive					
HEB	12.50	4.17	5.21	2.08	5.99
FEB	7.29	4.17	3.13	2.08	4.17
Preview	12.50	5.21	3.13	4.17	6.25
Ignoring Negative					
HEB	16.67	14.58	4.17	1.04	9.11
FEB	9.38	0.00	1.04	2.08	3.13
Preview	11.46	5.21	5.21	1.04	5.73

5.23 Discussion

The main aim of Experiment 7 was to provide a more powerful within-participants evaluation of whether ignoring negative faces is more difficult than ignoring positive faces. As in the previous experiments, there was a search advantage for negative valenced faces, compared with positive faces in standard search conditions (search rates were approximately double). We also found a partial, although robust, preview benefit for both ignoring positive and negative faces. However, of most interest was whether it would be more difficult to ignore negative faces compared to positive faces. On this, the results were quite clear. Not only was there a non-significant difference between the efficiency of ignoring positive and negative faces, (based on overall RTs and slopes) but the numeric trend went in the opposite direction (ignoring positive faces was more difficult). Thus, these data strongly contradict the suggestion, based on the comparison between Experiments 5 and 6, that negative faces may be more difficult to ignore than positive ones.

Chapter 6

The time course of preview benefit with positively and negatively valenced faces

(This chapter has been adapted from the paper "Visual marking and facial affect: Can an emotional face be ignored?" accepted for publication in *Emotion*.)

6 The time course of preview benefit with negatively and positively valenced faces

6.1 Abstract

Previewing schematic emotional faces (positively and negatively valenced) in preview search elicits a robust, but partial, preview benefit, with no evidence of differential processing between stimulus valence. Four experiments investigated whether reducing (250-750 ms) or extending (1000–3000 ms) the preview duration affects the preview benefit, and whether negative and positive facial expressions differ in the extent to which they can be ignored at these preview durations. In this instance, negative faces were more difficult to ignore than positive faces, but only at short preview durations. This is consistent with evidence of rapid differentiation of valence (e.g., N.K. Smith et al., 2003) and impaired disengagement (e.g., E. Fox et al., 2001; 2002; G. Georgiou et al., 2005) from negative faces at short latencies. Furthermore, a full preview benefit was not obtained with face stimuli even when the preview duration was extended up to 3 s, suggesting that faces are particularly resistant to suppression.

6.2 Introduction

Thus far, the ability of observers to ignore negatively valenced compared with positively valenced faces has been evaluated. Two main findings have emerged: (i) a full preview benefit has not been observed, with search efficiency in the preview conditions falling between the two baselines. This suggests that, in contrast to other types of stimuli (e.g., letters, simple shapes), face stimuli cannot be fully ignored, and that (ii) negative faces appear to be ignored as easily as positive faces. This is perhaps surprising, given the numerous previous findings showing that attention is allocated more rapidly, and tends to be held for longer, by negative rather than positive stimuli (e.g., Fox et al., 2001; Fox et al., 2002; Georgiou et al., 2005; Eastwood et al,. 2001; Hansen & Hansen, 1988; Hampton et al., 1989). These negative valence effects may well be due to negative stimuli signaling a potentially greater threat to our survival or well-being. Thus, one might also have expected that negative faces would be more difficult to ignore than positive faces.

That said, to this point, the standard preview paradigm has been adopted, with a preview duration of 1 s. Given that, in previous work (i.e. in visual search, cueing and flanker studies; see Eastwood et al., 2001; Fox et al., 2000, 2001, 2002; Georgiou et al., 2005; Fenske & Eastwood, 2003), the attentional properties of valenced faces have been evaluated by temporal performance indicators (i.e. RT, or search slope functions derived from plotting RT against display size), it is possible that restricting valenced face preview to a single temporal window may have excluded valenced-based performances at other preview durations. Moreover, it is important to recognize that this constraint may be construed bi-directionally; although negative stimuli have been shown to guide attention to their location more rapidly (e.g., in visual search studies; see Eastwood et al., 2001; Fox et al., 2000), they have also been shown to hold attention at their location (e.g., with delayed disengagement in cueing, see Fox et al., 2001; Georgiou et al., 2005). Thus, accommodating the temporal requirements of these effects will necessitate adjusting the preview duration to examine longer and shorter time periods. In turn, this may also impact on temporal aspects of the preview benefit itself.

6.2.1 *The time course of the Preview Benefit*

Several studies have previously examined the time course of the performance advantage derived from presenting a subset of distractors (typically, with a 1000ms interval between preview onset and the final search array; the *preview benefit*). Watson & Humphreys (1997) initially demonstrated that a stimulus onset asynchrony (SOA) of at least 400 ms was required for the preview benefit to accrue optimal effectiveness. However, their study (see Experiment 3a), did not include either HE or FE baseline conditions (by which it is possible to evaluate the relative efficiency of search in the preview condition), or varying display sizes, which would enable direct comparability of search efficiency, via search slope functions.

Further examination of the time course of preview benefit (e.g., Humphreys et al., 2004), has included both behavioural and electrophysiological measures (Positron Emission Tomography; PET). This study confirmed that a period of approximately 500 ms was required for effective filtering of old items from search, with search rates and RTs reaching asymptote after 600 ms (also, this study addressed those methodological issues remaining in question from Watson & Humphreys' study, 1997; see above). In addition, Humphreys et al., (2004) found electrophysiological evidence for increasing selective activation of parietal-occipital areas as preview durations increased (from 300-900ms), consistent with targets being filtered in parallel, in a visual search task (and concurrent with enhancement of search performance).

Alternative accounts of the preview benefit have proposed mechanisms other than the top-down, inhibitory filtering, proposed by Watson & Humphreys (1997, 1998); and these relate mainly to processes of temporal segmentation (e.g., Jiang, Chun & Marks, 2002; Jiang & Wang, 2004) and bottom-up attention capture from new item onset (e.g., Donk, 2005, 2006; Donk & Theeuwes, 2001, 2003; Donk & Verburg, 2004). In turn, these alternate accounts also indicate differential time courses for the resulting performance advantage, in line with the nature of the mechanisms proposed to underpin them. For example, effective temporal segmentation between visual displays can be demonstrated at an interval of approximately 100ms between old and new items (e.g., Yantis & Gibson, 1994).

Donk & Verburg (2004) looked to support the claim of bottom-up stimulus-driven preview advantage by demonstrating that an initial display of old items did not impair subsequent search, even though these appeared just 50 ms prior to the onset of the new items. From these data, Donk & Verburg argued that the preview benefit is instantaneous, and that their findings were inconsistent with accounts of preview benefit that required either slow inhibitory processing (i.e. *Visual marking*; Watson & Humpreys, 2007), or that reflected more rapid processing, but for which a 50 ms interstimulus interval was insufficient (i.e. *Temporal segmentation*; Gibson & Yantis, 1994; Jiang, Chun & Marks, 2002). However, as Donk & Verburg's (2004) preview stimuli were isoluminant, and such stimuli have been shown subsequently to have little impact on non-isoluminant items, even when presented concurrently (Braithwaite, Hulleman, Watson, & Humphreys, 2006), these findings should be treated with caution (see also Braithwaite, Hulleman, Watson, & Humphreys, 2007; for further discussion).

Clearly those theoretical standpoints (i.e. the *new item onset* and *temporal segmentation* accounts) are not consistent with a mechanism that requires a relatively lengthy process of inhibitory filtering. However, in respect of the latter example, Humphreys,Watson and Joliecœur (2002) interpreted the 100ms interval shown by Gibson & Yantis (1994) as playing a role in the effective prioritization of new over old items (i.e. as a portion of the time course for an inhibitory filtering mechanism). They suggested this interval was used to encode a representation of the previewed items and subsequently, to de-prioritize representations of these items, thus facilitating search amongst the new items.

Humphreys, Stalmann & Olivers (2004) also strengthened the case for a relatively slow, top-down, inhibitory mechanism to underlie preview benefit, by exploring time course via a probe dot detection task (see also Watson & Humphreys, 2000). In this study, Humphreys et al. found that detection of probes was facilitated at the locations of old items (relative to detection at locations of new or neutral items) when these were presented 200ms after the onset of the preview, but were progressively more difficult to detect with SOA of 800ms and 1200ms. Further, probes located at old items were less effectively detected, compared to those at neutral or new items, at both these intervals. However, where probe detection was presented as the main task, there was no difference in detection performance at any location. Taken as a whole, these findings support the notion of a i) relatively slow, ii) inhibition-based mechanism, requiring the iii) top-down influences of the observer's intention, and iv) developing in efficacy over time, reaching asymptote with the HEB at approximately 600 ms.

6.2.2 *Temporal aspects of valence effects*

In all experiments presented in Chapter 5, the old (to be ignored) preview faces have always been presented for the standard preview interval of 1000 ms before the new (to be searched) items have been shown. It is possible that any differences in the ability to ignore positive and negative faces occur relatively early following the presentation of the preview display, and thereafter, dissipate through the 1000 ms preview period. Indeed, neurophysiological evidence suggests that there is an initial rapid differentiation of valenced stimuli (see Smith et al., 2003) at relatively short latencies, (80-100 ms; see also Eimer & Holmes, 2002; Vuilleumier & Pourtois, 2007, Ashley, Vuilleumier & Swick, 2003, for related findings with face stimuli, and Eimer & Holmes, 2007, for a review).

Moreover, previous studies examining attentional effects of schematic faces in a cueing paradigm (see Fox et al., 2001) have demonstrated an impaired ability to disengage from negatively valenced faces (angry facial stimuli) at much shorter latencies than those used in Experiments 3,5, 6 and 7 (i.e. at 250- 300 ms post stimulus onset). It follows that any differences in the ability to ignore negative and positive faces might only emerge at shorter preview durations.

Conversely, the phenomenon of prolonged dwell time on negative, particularly threatening, faces (see Fox et al., 2001; Georgiou et al., 2005) might be thought of adaptive, insofar as it would enable further evaluation of a potential source of threat and planning of a suitable response. Thus, it could be argued that it would be behaviourally inappropriate to fully suppress a negative face (compared with a positive one), and evidence of differential processing would not emerge until sufficient time for this evaluation has elapsed. In fact, in the case of non-valenced stimuli, previous work has shown that some suppression-resistant stimuli (e.g., those isoluminant with their background) require more than 1000 ms in order for them to be fully suppressed in preview search (e.g., Braithwaite et al., 2006**).** This suggests that emotionally valenced stimuli (and particularly, those that have particular behavioural significance, such as negative faces) might require additional time to be ignored effectively.

6.2.3 *Purpose of the current chapter*

In broad terms, this chapter aims to evaluate search performance under conditions of both reduced (250-750 ms) and extended (1000-3000 ms) preview duration. More specifically, it aims primarily to explore whether positively and negatively valenced faces elicit differential processing at preview durations other than that those typically used in the standard paradigm (i.e. 1000ms). Secondly, it examines whether any differences attributable to valence interact with those variations made to the preview duration. Finally, this chapter aims to ascertain whether it is possible to obtain a full preview benefit for valenced schematic faces.

If, in line with evidence that emotional faces and other valenced stimuli elicit differential processing shortly after onset (e.g., Eimer & Holmes, 2002, 2007; Vuilleumier & Pourtois, 2007; Ashley et al., 2003; Smith et al., 2003), then one would expect to find differences between ignoring positive and negative faces for preview durations of less than 1000 ms. With respect to the finding of a partial preview benefit (see Experiments 3, 5, 6 and 7; Chapter 5), it is also possible that, if faces represent a particularly salient and powerful stimulus for the attentional system, a 1000 ms preview could be an insufficient period of time to fully suppress facial stimuli (either positive or negative). Thus, if fully suppressing face stimuli takes additional time, as is the case with isoluminant stimuli (Braithwaite et al., 2006), then we might expect to find an increasing (perhaps full) preview benefit beyond a 1000 ms preview duration. The following experiments addressed these issues directly by varying the preview period from 250 ms to 750 ms (Experiment 8) and 1000 ms to 3000 ms (Experiment 9).

6.3 Experiment 8a & 8b: Reducing the preview duration with positive and negative preview displays[11]

Experiment 8 examined preview search performance with positively (Experiment 8a) and negatively (Experiment 8b) valenced preview displays, using preview durations of 250, 500 and 750 ms.

6.4 Method.

6.4.1 *Participants*

Thirty six students (13 male, 23 female) aged 18 to 36 years (M=20.9) from the University of Warwick participated, either for payment or course credit. Eighteen participants were randomly allocated to each experiment (8a and 8b), and all reported normal or corrected to normal vision.

[11] I would like to acknowledge the kind assistance of Liam Gilligan and Tom Barry in collecting the data in this experiment.

6.4.2 *Stimuli and Apparatus*

Stimuli and apparatus were identical to those in Experiment 5, 6 and 7.

6.4.3 *Design and Procedure*

Each participant completed 5 blocks of experimental trials, consisting of two HEB blocks and 3 preview search blocks (one block for each of the 3 durations). Each block of preview trials contained 112 experimental search trials, with a target present on the left or right of the display and 16 catch trials, where no target was present. Within each block there was an equal number of each displays size (4, 8, 12, 16 items), and target side was combined equally with all display sizes. A preview search trial in Experiment 8a consisted of a preview of positive faces, after which a search display of neutral distractor faces and a negative target appeared.

In Experiment 8b, the preview consisted of negative faces followed by neutral faces and a positive target. Directly before each preview block was a 20-trial practice block. Half the participants received the shortest preview condition first and the longest last, and for the other half this was reversed. In addition to the preview conditions, participants also completed two blocks (56 search trials and 8 catch trials) of a HEB condition (one directly before and one after the three preview blocks) which consisted of only the second set of elements from the associated preview conditions.

6.5 Results

In this instance, the emphasis was on how preview search performance would change over time, across the various conditions. Previous experiments have already established the characteristics of preview search as a function of valence based on both search slopes and overall RT measures. Accordingly, for clarity of analysis and presentation here, search slope analyses *only* (which have been taken in previous work to be the most reliable indicator of preview search performance) will be used. To achieve this, the data were first screened as described in Experiment 3, and search slopes were then calculated individually for each participant and condition (based on correct responses only). These slope data were then used as the primary measure in these analyses. Figures 6.1a and 6.1b (showing mean correct RT against display size, by search condition) have been included to enable straightforward comparison of RTs between experiments.

6.5.1 *Experiment 8a: Ignoring positive faces*

Mean search slope statistics are shown in Table 6.1. The RTs from the two HEB blocks were examined for differences attributable to block order (whether HEB block was presented at the start or end of the procedure). Paired samples t-tests showed no significant difference, in either overall RTs, $t(17) = 0.36$, $p = .72$, or Search Slopes, $t(17) = 0.25$, $p = .81$ and so, the data from both HEB blocks were combined.

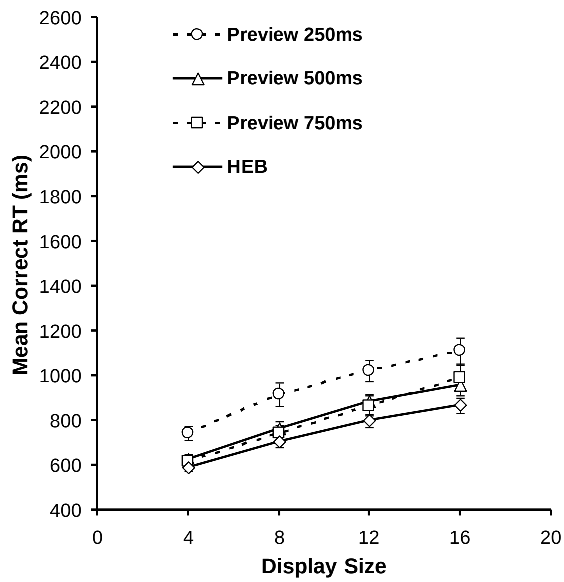
6.5.2 *Search slope data*

As changes in search efficiency as a function of preview duration were of most interest, search slopes for each condition (HEB, 250, 500, 750 ms preview), and were analyzed with a one-way within-subjects ANOVA. As shown in Table 6.1, search was most efficient in the HEB (23 ms/item), and least efficient in the preview conditions (approximately 30 ms/item). However, the three preview conditions did not differ significantly; all *Fs*<1.

Table 6.1 Search slope statistics for Experiment 8a, ignoring positive preview faces, by block type and preview duration

	Block Type and Preview Duration			
	HEB	Preview		
Slope Statistics		250 ms	500ms	750 ms
Slope (ms/item)	23.00	30.08	27.93	31.28
Intercept (ms)	510.28	645.94	528.81	590.16
R^2	0.99	0.97	0.98	1.00

A) Ignoring positive faces



B) Ignoring negative faces

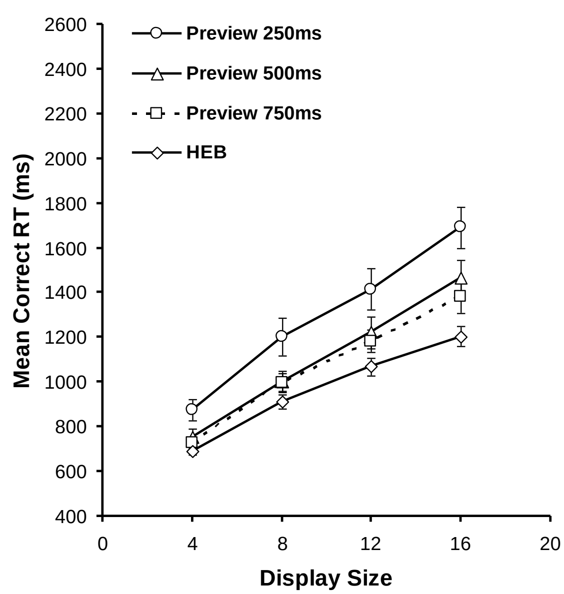


Figure 6.1 Mean correct RTs for ignoring a positive preview (Panel A) and negative preview (Panel B) as a function of condition and display size for Experiment 8. Error bars indicate ±1 standard error.

6.5.3 *Error data*

Mean percentage error rates are shown in Table 6.2. Error data from HEB blocks was examined for differences attributable to block order. Paired sample t-tests showed no significant difference between the blocks, in both search trial errors, $t(17)= 0.96$, $p= .35$, and catch trial errors, $t(17)= 0.27$, $p= .79$, therefore, both search error and catch error data were collapsed across the two blocks. Generally, error rates on search trials were low (3.39%), and were transformed logarithmically before analysis. A 4 (Search Condition) x 4 (Display Size) ANOVA, revealed a significant main effect of Search Condition, $F(3,51)= 3.14$, $MSE= 0.12$, $p <.05$, with fewer errors produced in the HEB. In addition, error rates increased with Display Size, $F(3,51)= 4.37$, $MSE=0.21$, $p<.05$ and this increase was greatest in the preview conditions, $F(9,153)=2.95$, $MSE= 0.10$, $p<.05$.

Taking preview trials alone, there remained a significant main effect of Display Size, $F(3,51)=5.79$, $MSE= 0.25$, $p<.005$, although the main effect of Condition, $F<1$, did not prove reliable. The Condition x Display Size interaction, $F(6,102)=2.17$, $MSE= 0.08$, $p=.05$, approached significance. Catch trial error rates were relatively low overall (4.34%) but increased as Display Size increased, $F(3,51)=9.51$, $MSE= 126.25$, $p<.001$. However, neither the main effect of Condition nor the Condition x Display Size interaction approached significance, both *F*s < 1.

Table 6.2 Mean percentage error rates for Experiment 8a, by block type, preview duration and display size

	Display Size				
	2	4	6	8	
	4	8	12	16	Mean
Search Trials					
HEB	1.59	1.19	1.79	1.19	1.44
Preview: 250ms	0.79	1.19	4.17	5.36	2.88
Preview: 500ms	1.39	1.98	3.37	3.77	2.63
Preview: 750ms	1.98	2.18	2.58	3.17	2.53
Catch Trials					
HEB	15.28	4.17	2.78	4.17	6.60
Preview: 250ms	11.11	5.56	5.56	6.94	7.29
Preview: 500ms	13.89	5.56	4.17	1.39	6.25
Preview: 750ms	8.33	5.56	4.17	0.00	4.51

6.5.4 *Experiment 8b: Ignoring negative faces*

There were no significant differences between the two HEB blocks, for either overall RTs, *t*(17)= 0.23, *p*= .82, or search slopes, *t*(17)= 0.77, *p*= .45, therefore, data were collapsed across the two blocks.

6.5.5 *Search slope data*

There was a significant main effect of Search Condition (HEB, 250, 500, 750 ms preview), *F(*3,51)=14.49, *MSE*= 128.84, *p*=.001. As shown in Table 6.3, slopes decreased as a function of preview duration and were shallowest.

Table 6.3 Search slope statistics for Experiment 8b, ignoring negative preview faces, by block type and preview duration

	Block Type and Preview Duration			
	HEB	Preview Duration		
Slope Statistics		250 ms	500ms	750 ms
Slope (ms/item)	42.30	66.65	58.65	53.83
Intercept (ms)	545.64	627.64	524.73	532.79
R^2	0.99	0.99	1.00	0.99

in the HEB. Considering preview slopes alone, there remained a significant main effect of Preview Duration, $F(2,34)=5.69$, $MSE= 132.58$, $p=.05$, indicating that search efficiency increased with preview duration.

6.5.6 *Error data*

Error rates are shown in Table 6.4. There was no significant difference between error rates in the first and last HEB blocks, for both search, $t(17)= 1.23$, $p= .24$, and catch trials, $t(17)= 0.37$, $p= .72$, therefore the data were collapsed across the two blocks. Generally, error rates in search trials were low overall (3.39%), and therefore, data were transformed as described above.

A 4 x 4 (Search Condition x Display Size) ANOVA revealed a main effect of Display Size, $F(3,51)= 13.08$, $MSE=0.20$, $p<.001$ and a significant Condition x Display Size interaction, $F(9,153)=3.42$, $MSE= 0.10$, $p<.005$. Errors increased with display size and this increase tended to be larger in the preview conditions. However, the effect of Search Condition, $F(3,51)= 1.58$, $p=.21$, did not approach significance. Taking preview trials alone, there remained a significant main effect of Display Size, $F(3,51)=19.24$, $MSE= 0.18$, $p<.001$, although the Condition x Display Size interaction did not prove statistically reliable, $F < 1$. However, there was a trend towards differential processing between preview durations, $F(2,34)=2.62$, $MSE = 0.10$, $p= .09$, with more errors being made at the shortest preview duration (250 ms).

Table 6.4 Mean percentage error rates for Experiment 8b, by block type, preview duration and display size

	Display Size				
	2 4	4 8	6 12	8 16	Mean
Search trials					
HEB	2.78	3.57	3.17	3.17	3.17
Preview: 250ms	1.59	2.58	4.56	7.54	4.07
Preview: 500ms	0.99	2.18	4.17	5.75	3.27
Preview: 750ms	0.20	1.98	3.77	6.15	3.03
Catch trials					
HEB	8.33	4.17	4.17	4.17	5.21
Preview: 250ms	5.56	1.39	2.78	1.39	2.78
Preview: 500ms	5.56	2.78	1.39	4.17	3.47
Preview: 750ms	13.89	5.56	4.17	0.00	5.90

Catch trial error rates were also low overall, (4.34%). Errors decreased with Display Size, $F(3,51)=5.20$, $MSE = 100.93$, $p<.005$, however, neither the main effect of Condition nor the Condition x Display Size interaction approached significance, both Fs < 1.01

6.6 Comparison of search slope data across Experiments 8a & 8b

To determine whether the time course for ignoring negative and positive faces differed, the slopes from the preview conditions of Experiment 8a (ignoring positive faces) and 8b (ignoring negative faces) were compared using a 3 (Preview Duration) x 2 (Experiment 8a/8b) mixed ANOVA. Overall, search slopes were greater when ignoring negative faces $F(1,34)= 40.34$, $MSE= 600.23$, $p<.001$, and there was a trend for search slopes to decrease with increasing preview duration, $F(2,68) = 2.90$, $MSE = 124.25$, $p=0.06$. However, of most interest was a significant Preview Duration x Experiment interaction, $F(2,68)=3.59$, $MSE= 124.25$, $p<.05$, showing that search slopes decreased as a function of preview duration when ignoring negative faces, but remained relatively constant when ignoring positive faces.

6.7 Discussion

As in previous experiments (Experiments 3-7), there was an advantage for detecting a negative compared with a positive target, based on search slope measures [12].

[12] As a point of secondary interest (and, as in the previous experiments), there was also an overall RT advantage (collapsed across condition and display size) for detecting a negative (823.2 ms) compared with a positive target (1106.1 ms), $t(34) = 5.05$, $p<.001$.

However, the main aim of Experiment 8 was to determine whether the time course for ignoring positive and negative faces differed over relatively short preview durations (250-750ms). One should note that the lack of a FEB in this experiment prevents the calculation of a preview benefit efficiency measure. Nonetheless, consistent with Experiments 3 to 7, search in the preview conditions was less efficient overall than search in the HEB, suggesting that a full preview benefit was not obtained. However, of most interest, there were clear differences in the time course of ignoring positive compared with negative faces. When ignoring positive faces, preview search was relatively efficient even with a preview duration of 250 ms, and remained relatively constant as the duration increased. In contrast, when ignoring negative faces, preview search was relatively inefficient at the shortest preview duration, but became more efficient as the preview duration increased.

This finding is consistent with the well-documented negative superiority effect, previously demonstrated in visual search tasks (i.e., Hansen & Hansen, 1988; Hampton et al., 1989; Eastwood et al., 2001; Fox et al., 2000; Öhman et al., 2001) and those using a cueing paradigm (i.e., Fox et al., 2001; Fox et al., 2002; Georgiou et al., 2005). These studies have illustrated that negatively valenced faces both draw and hold attentional resources, a finding which was, somewhat surprisingly, unsupported by Experiments 5-7 (Chapter 5). However in this instance, the difference between ignoring negative and positive faces at short previews suggests that valence-based effects interact with the temporal aspects of the standard preview search paradigm, and that whilst positive affective faces can be ignored effectively following relatively brief preview durations, the same is not true of negative faces.

6.8 Experiment 9a & 9b: Increasing the preview duration with positive and negative preview distractors

Experiments 3 to 7 (Chapter 5) have demonstrated a robust, but partial preview benefit when ignoring face stimuli. However, the lack of a full benefit might be because 1000 ms is insufficient time to fully suppress face stimuli (perhaps due to their strong ecological importance) compared with other less socially relevant stimuli (e.g., abstract letters, shapes). Accordingly, Experiment 9 examined whether extending the preview duration up to 3000 ms would produce a full (or at least, an increased) preview benefit (cf. Braithwaite et al., 2006).

6.9 Method

6.9.1 *Participants*

Twenty four students at the University of Warwick (20 female, 4 male) aged 18 to 28 years (*M*=20.17) participated in this study, either for payment or course credit. Twelve participants were randomly allocated to each version of the experiment, and all reported normal or corrected to normal vision.

6.9.2 *Stimuli and Apparatus*

All stimuli and apparatus were identical to those in Experiments 8a and 8b.

6.9.3 *Design and Procedure*

Design and procedure was identical to Experiment 8a and 8b, except that preview durations of 1000, 2000 and 3000 ms were used instead of 250, 500 and 750 ms.

6.10 Results

6.10.1 *Experiment 9a: Ignoring positive faces*

Data were screened as described in Experiment 3. Paired sample t-tests showed no significant difference between the two HEB blocks, in either overall RT, $t(11)= 0.35$, $p= 0.73$, or search slopes, $t(11)= 0.36$, $p= 0.73$, therefore, data was collapsed across the two blocks. Search slope statistics are presented in Table 6.5. Figures 6.2a and 6.2b (showing mean correct RT against display size, by search condition) have been included to enable straightforward comparison of RTs between experiments.

Table 6.5 Search slopes for Experiment 9a, ignoring positive previewed faces, by block type and preview duration

	Block Type and Preview Duration			
	HEB	Preview Duration		
Slope Statistics		1000 ms	2000ms	3000 ms
Slope (ms/item)	21.31	23.64	25.32	33.38
Intercept (ms)	536.96	578.47	543.39	509.13
R^2	0.94	0.98	1.00	0.98

6.10.2 *Search slope data*

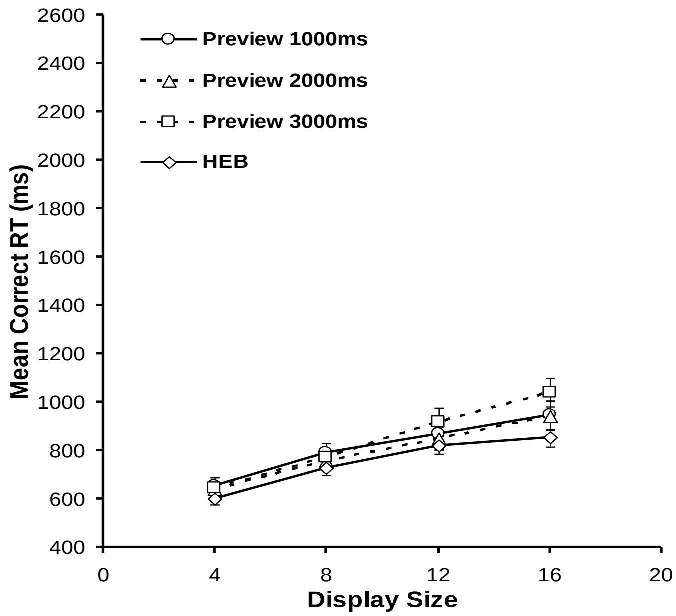
A one-way repeated-measure ANOVA revealed that search efficiency differed across search conditions (HEB, 1000, 2000, 3000 ms preview), $F(3,33)=3.96$, $MSE = 83.20$, $p<.05$, with search being more efficient in the HEB than in the preview conditions. However, taking the preview conditions alone, there remained a significant main effect of Preview Duration, $F(2,22)=3.42$, $MSE= 95.04$, $p= .05$. As shown in Table 6.5, slopes remained relatively flat, and then increased between 1000 and 3000 ms.

6.10.3 *Error data*

Error data is shown in Table 6.6. There was no significant difference between error rates in the two HEBs for both search, $t(11)= 0$, $p= 1$, and catch trials, $t(11)= 1.60$, $p= .14$, and so these data were collapsed. Search error rates were low overall (2.05%), and thus, were logarithmically transformed in accordance with previous data treatment.

Errors tended to increase with Display Size, $F(3,33)=2.37$, $MSE= 0.22$, $p=.09$. However, neither the main effect of Condition, nor the Condition x Display Size interaction reached significance, both $Fs <1$. Considering just the preview conditions, no main effects or their interaction proved significant, all $Fs < 2.09$, all $ps > .11$. The overall error rate on catch trials was 5.86%. Error rates were greater at the smaller display sizes, $F(3,33)=4.06$, $MSE= 118.47$, $p<.05$. However, neither the main effect of Condition, nor the Condition x Display Size interaction approached significance, both $Fs < 1.61$, $ps > .20$.

A) Ignoring positive faces



B) Ignoring negative faces

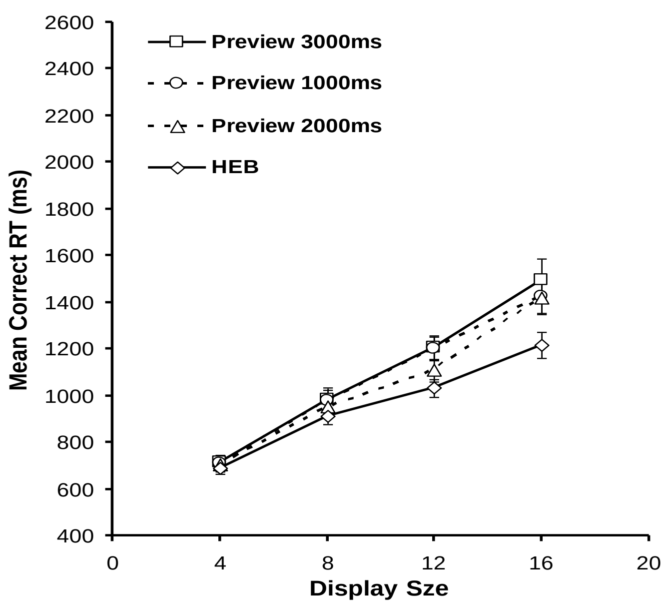


Figure 6.2 Mean correct RTs for ignoring a positive preview (Panel A) and negative preview (Panel B), as a function of condition and display size for Experiment 9. Error bars indicate ±1 standard error.

Table 6.6 Mean percentage error rates for Experiment 9a, by block type, preview duration and display size

	Display Size				
	2	4	6	8	Mean
	4	8	12	16	
Search trials					
HEB	1.79	1.79	2.38	2.38	2.09
Preview 1000ms	0.89	0.89	2.08	3.87	1.86
Preview 2000ms	0.89	2.98	2.08	2.98	2.09
Preview 3000ms	0.60	1.79	2.38	2.98	1.79
Catch trials					
HEB	10.42	6.25	2.08	8.33	6.77
Preview 1000ms	12.50	4.17	4.17	6.25	6.77
Preview 2000ms	10.42	6.25	4.17	4.17	6.25
Preview 3000ms	8.33	2.08	2.08	2.08	3.65

6.10.4 *Experiment 9b: Ignoring negative faces*

There were no significant differences between the two HEBs, in either RT, $t(11)= 0.32$, $p= .76$, or search slopes, $t(11)= 0.48$, $p= .64$, therefore, data was collapsed across the two blocks. Table 6.7 shows the search slope statistics.

6.10.5 *Search slope data*

Search was more efficient in the HEB than in the Preview Conditions (1000, *2000, 3000 ms preview), $F(3,33)=7.01$, $MSE= 143.22$, $p<.005$. However, search efficiency did not differ as a function of Preview Duration, $F < 1$.

Table 6.7 Search slope statistics for experiment 9b, ignoring negative previewed faces, by block type and preview duration

	Block Type and Preview Duration			
	HEB	Preview Duration		
Slope Statistics		1000 ms	2000ms	3000 ms
Slope (ms/item)	42.62	59.08	57.76	63.73
Intercept (ms)	536.58	486.91	469.17	462.07
R^2	0.99	1.00	0.98	1.00

6.10.6 *Error data*

Error rates were low overall (4.09%) and are shown in Table 6.8. There was no significant difference between the first and last HEB blocks, in either search trial errors, $t(11)= 1$, $p= .34$, or catch trial errors, $t(11)= 0.89$, $p= .39$, and so the data were collapsed across the two blocks.

Table 6.8 Mean percentage error rates for Experiment 9b, by block type, preview duration and display size

	Display Size				
	2	4	6	8	Mean
Search Trials	4	8	12	16	
HEB	1.49	2.68	2.68	4.46	2.83
Preview 1000ms	1.19	3.27	5.95	9.82	5.06
Preview 2000ms	1.19	1.79	5.95	7.14	4.02
Preview 3000ms	0.60	2.38	7.14	7.74	4.46
Catch Trials					
HEB	6.25	8.33	8.33	6.25	7.29
Preview 1000ms	10.42	4.17	8.33	6.25	7.29
Preview 2000ms	16.67	6.25	6.25	2.08	7.81
Preview 3000ms	18.75	4.17	0.00	6.25	7.29

Following log transformation of the data, a 4 (Condition) x 4 (Display size) ANOVA revealed main effects of Display Size, $F(3,33)=21.67$, $MSE= 0.12$, $p<.001$ and of Search Condition, $F(3,33)= 4.76$, $MSE= 0.11$, $p<.05$. with error rates increasing with increasing display size, and being higher in the shortest preview duration (1000ms). The Condition x Display size interaction, $F(9,99)=1.98$, $MSE= 0.13$, $p = .05$, was also significant.

Considering just the preview conditions, errors increased with Display Size, $F(3,33)=37.96$, $MSE= 0.08$, $p<.001$, however again, neither the main effect of Duration, nor the Duration x Display size interaction approached significance, both $Fs < 1.08$.

Catch trial error rates were 7.42% overall, and increased with Display Size, $F(3,33)= 4.32$, $MSE= 155.56$, $p<.05$. However, neither the main effect of Condition nor the Condition x Display Size interaction proved statistically significant, both Fs < 1.22, ps > .29.

6.11 Comparison of search slope data across Experiments 9a & 9b

A 3 (Preview duration, 1000, 2000, 3000 ms) x Experiment (9a/9b) mixed ANOVA revealed a main effect of preview duration that approached significance, $F(2, 44)= 2.98$, $MSE= 135.56$, $p=.06$, suggesting that search was less efficient when searching for a positive target, $F(1,22)= 41.68$, $MSE= 462.99$, $p<.001$. However, the Preview Duration x Experiment interaction did not approach significance, $F < 1$.

6.12 Discussion

As in the previous experiments, based on search slopes there was a clear search advantage for detecting a negative face target compared with a positive face target[13]. As for Experiment 8a/8b, it should be noted that a preview benefit efficiency measure could not be calculated. However, the main aim of Experiment 9 was to determine whether a full preview benefit would be obtained if the preview duration was extended up to 3s. This might be the case if fully suppressing socially relevant stimuli takes longer overall than suppressing more abstract stimuli. On this issue the results were clear, even with extended preview duration of 3s, search slopes in the preview condition did not reduce to the level obtained in the HEB. This means that even increasing the preview duration to 3s did not result in a full preview benefit. Furthermore, this finding held for ignoring both negative and positive valenced faces.

In summary, this chapter aimed to explore the temporal parameters of ignoring emotionally valenced faces. Given that, i) the predicted differential processing for negative faces had not been elicited (i.e. negative faces would be more difficult to ignore), and ii) a full preview benefit had not been demonstrated with facial stimuli, whether valenced or not, it was important to ascertain whether this might be a result of restricting preview duration to the standard 1s (i.e. Watson & Humphreys; 1997, 1998). When preview duration was shortened (to 250, 500 or 750ms), performance differences between ignoring negative and positive faces emerged.

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[13] There was also an overall RT advantage (collapsed across condition and display size) for detecting a negative target (800.1 ms) compared with a positive target (1040.3 ms), $t(22) = 4.47$ $p < .001$.

This showed that, although positive faces could be ignored successfully from 250ms onwards (note that this effect remained imperfect), suppressing negative faces was selectively impaired until the preview duration lasted between 750 and 1000ms. This is consistent with previous work (e.g., Fox et al., 2001) demonstrating impaired attentional disengagement from negative faces at similar latencies, and also neurophysiological evidence that positive and negative faces can be discriminated from each other equally rapidly (e.g., Eimer & Holmes; 2002, 2007).

However, when preview duration was extended (from 1- 3s) in order to evaluate whether this enabled facial stimuli to be fully ignored (see Braithwaite et al., 2006), no differential valence-based processing was evident. More importantly, a full preview benefit (i.e. search performance, equivalent to that in the HEB) was not demonstrated for either valence preview. This suggests that facial stimuli may be too behaviourally and visually salient for humans to ignore fully. Lastly, the search advantage for negatively valenced face targets was demonstrated throughout all experiments in this chapter.

Chapter 7

The effect of facial expression change on time-based visual selection

7 The effect of facial expression change on time-based visual selection

7.1 Abstract

The search advantage conferred by previewing a set of distractors (*the preview benefit;* D.G. Watson & G.W. Humphreys, 1997, 1998) can be disrupted by changes to old items that signify behavioural relevance; for example, high level changes to shape or identity (D.G. Watson & G.W.Humphreys, 2002, 2005; D.G. Watson, J.J. Braithwaite & G.W. Humphreys, 2008). The experiments reported here explored the impact of changes to the expressions displayed by previewed schematic faces (made concurrently with the onset of the full search array), and any differential processing attributable to the valence of the expression change. Both Experiments 1 and 2 demonstrated a clear disruption of the preview benefit, with little impact of expression valence. This indicates that changes to the facial expression of previewed faces are of sufficient behavioural importance to re-engage attention and compete with new items for selection.

7.2 Introduction

Faces represent a particularly salient stimulus to the human visual system, and are said to be the visual stimulus to which humans are exposed most frequently over the duration of their lifespan (see Pascalis & Kelly, 2009; for further discussion). Perhaps unsurprisingly then, there is considerable evidence of mechanisms specialized to facilitate efficient processing of facial stimuli in a wide range of circumstances (e.g., subcortical face detection; Johnson, 2005; holistic processing, Farah et al., 1998; processing outside conscious awareness, e.g., Morris et al., 1998) Moreover, as it is possible to say that faces (and here, specifically human faces) are constantly dynamic; with processing of changing facial expression, gaze direction and face orientation being necessary to fluent social interaction (e.g., Pascalis & Kelly, 2009; Carey, 1992) in turn, we might also argue that this is reflected in the flexibility of the specialized neural circuitry suggested to underlie their processing.

Thus, it is surprising that most studies addressing aspects of facial processing, focus on the underlying mechanisms of non-dynamic faces, both in the sense of stimulus motion and change. In terms of their salience to the visual system, a significant proportion of this literature has explored the deployment of visual attention to facial stimuli; for example, the ability of faces to effectively capture attention in visual search (e.g., Hansen & Hansen, 1988; Hampton et al., 1989; Fox et al., 2000; Eastwood et al., 2001), or to hold attention once engaged (e.g., Fox et al., 2001; 2002; Georgiou et al., 2005), particularly where a negative facial expression is displayed. This preferential processing (often known as the *threat superiority effect*; see Öhman et al., 2001), refers to the ability of faces displaying negative facial expressions (e.g., sadness, anger, fear) to guide attention more efficiently to themselves, when presented amongst neutral (i.e. Eastwood et al., 2001) or positive faces (i.e. Hansen & Hansen, 1988), in comparison to the reverse display configuration (i.e. a positive face target amongst neutral or negative distractors). Although this effect is not without challenge (e.g., Williams et al., 2005b; Juth et al., 2005), this processing advantage for negative faces has been demonstrated widely, with a number of different facial stimuli (e.g., Hansen & Hansen, 1988; Öhman et al., 2001; Eastwood et al., 2001; Horstmann, 2007) and in a number of attentional paradigms (e.g., visual search, cueing and flanker tasks).

In an exception to the majority of the literature, Horstmann and Ansorge (2009) have recently examined the effects of dynamic changes to facial stimuli. They reasoned that real faces communicate socio-emotional information over time, and that facial expressions are dynamic events, not simple representations of a static *apex* (i.e. the most extreme state of the expressive movement). Furthermore, they anticipated that there would be enhanced differential processing of dynamic valenced faces, given that these stimuli have demonstrated heightened emotional effects (i.e. Rubenstein, 2005; Sato & Yoshikawa, 2007) and enhanced salience of facial expression (i.e. Rubenstein, 2007).

Search for negative faces amongst positive, and in dynamic rather than static expression displays, demonstrated the performance advantage predicted. However, Horstmann and Ansorge (2009) concluded that this was the result of increased facial movement when expression changed from neutral to negative, as opposed to from neutral to positive (see also Hillstrom & Yantis, 1994; Abrams & Christ, 2003; Franconeri & Simons, 2003; for evidence that the onset of motion can attract attention automatically). In fact, when the authors controlled for facial movement, effects of negative superiority and dynamic expression advantage dissipated (see Experiments 2 and 3).

Nonetheless, what might have appeared prima facie, to be an experimental confound, was attributed by Horstmann and Ansorge to a potentially adaptive mechanism underlying the processing of threat per se. They argued that threat expressions, such as anger, may have evolved from the most extensive facial movement precisely to ensure optimal communication to conspecifics. Moreover, this could be enhanced by a potential *sensory bias* effect (see also Horstmann & Bauland, 2006; for additional discussion of this debate), where species ancestral to Homo Sapiens evolved to be sensitive to low-level perceptual features (such as the simple motion detection required for hunting or predator avoidance), prior to their adaptation to facial expression. However, this is not to preclude the possibility that there is a specialized behaviour module in humans, attuned for emotional facial expression (see Horstmann & Bauland, 2006; and also Ohman & Mineka, 2001; Tooby & Cosmides, 1992).

7.2.1 *Ecological importance of changes in the visual environment*

Outside the face processing literature, the effects of changes to the appearance of items in the visual field have been examined in a number of ways (e.g., item onset and offset, motion-based changes; Yantis & Jonides, 1984; Yantis & Hillstrom, 1994; Abrams & Christ, 2003; Franconeri & Simons, 2003; von Mühlenen & Lleras, 2007). Most importantly, being able to prioritize specific items in our visual field (for example, those that have changed in identity, or those that have moved towards us) suggests an adaptive capacity to differentiate between which aspects of the environment are relevant to our current behavioural goals, and which are not. Changes to viewed items are visual events that might attract differential processing according to their potential real world impact on an organism.

For example, where a change in luminance results from the appearance of a new item in the visual field, we might expect the change to represent a behaviourally relevant occurrence, and attentional resources to be allocated accordingly (i.e. via rapid, automatic stimulus-driven processing, such as attention capture). Indeed, previous research has shown that the appearance of such new objects tends to capture attention automatically (e.g., Yantis & Jonides, 1984; Theeuwes, 1991, 1995). Conversely, where a similar change in luminance indicates a goal or adaptively-irrelevant event (such as a shadow passing across the visual field), an adaptive mechanism might preclude the deployment of attention to a location where no behaviourally useful information would be obtained.

7.2.2 *The effects of change in preview search*

In terms of marrying the concepts of time-based selection and behaviourally-relevant changes to stimuli, Watson and Humphreys demonstrated (in their original work documenting the effects of preview search; 1997) that a simultaneous change in luminance and shape at the location of a previewed item when the new items were added abolished the preview benefit. Later work (Watson & Humphreys, 2002) replicated this effect, and also distinguished between the two aspects of the visual change. Here, they showed that a change in preview item luminance or colour (without an accompanying shape change), did not affect the preview benefit, whereas the reverse (i.e. a shape change, without global luminance change) eliminated the preview benefit completely (see also, Watson, Braithwaite & Humphreys, 2008). Similarly luminance changes or new objects appearing at locations not associated with the old previewed items, and therefore, of no behavioural relevance to the task of ignoring them were not disruptive (unless they shared the colour of the new items; Watson & Humphreys, 2005). Finally, large luminance changes as a result of previewed becoming occluded and then un-occluded, also still result in a robust preview benefit (Kunar, Smith, Humphreys, & Watson, 2001).

Thus, it can be argued that the mechanisms involved in the de-prioritization of old items and prioritization of new, are sensitive to the behaviourally-relevant changes to the old items, regardless of whether the changes are permanent or transitory. If such behaviourally relevant changes occur, then the status of the previewed item(s) appears to be *reset*, releasing them to compete strongly for attention.

In summary, although previous work has shown that the visual system ignores substantial changes to items that have already been suppressed (i.e. previewed), there is a limit to this ability. In particular, a change in shape appears to totally abolish the preview benefit. As Watson and colleagues argue (2008; see also Watson & Humphreys, 2002, 2005, for similar discussions), such changes are likely to be of greatest behavioural relevance because the visual change could indicate the appearance of a (perhaps previously camouflaged) new object or a change in the heading or direction of gaze of an already present object.

7.2.3 *Purpose of the current chapter*

These experiments aimed to investigate the effects of changes in facial expression in preview search. Prior work examining changes made to items in a previewed distractor set (i.e. Watson & Humphreys, 2002, 2005;Watson, Humphreys, &

Braithwaite, 2008; Kunar, Humphreys, Smith, & Hulleman, 2003b; Kunar et al., 2001;) has shown that certain types of changes (e.g. those that represent behaviourally important high level changes to shape or object identity) act eliminate performance benefits derived from previewing old items. Conversely, a *surface* change in luminance or colour does not affect preview benefit; eliciting a full performance advantage (Watson & Humphreys, 2002).

Thus, predicting the effects of facial expression change on the preview benefit is less than straightforward. In previous work, the overall physical change used to create a shape change has been quite large. For example, in Watson and Humphreys' study (2002), the preview items consisted of 2-segment right angle brackets which changed to letter Hs by the addition of 3 extra line segments to each item (see Figure 7.1, below). This change represented a size increase by a multiplier of 1.75. In contrast here, the changes were physically much smaller in terms of the number of pixels that changed. For example, changing from a neutral face to a sad face resulted in an addition of two pixels (i.e. a size increase by a multiplier of 1.01) and a change from a neutral face to a happy face increased the pixel number by six (i.e. by a multiplier of 1.04).

More importantly, the *overall* shape / identity of the previewed items remained much more constant than in previous work. That is, in Watson and Humphreys' study (2002), a right angle bracket to an H letter represents a substantial change in the i) number of pixels illuminated,[14] ii) overall luminance of the item, iii) overall size, and iv) the preview stimuli remained much more constant after the change (i.e. the preview stimuli remained as *faces* even after the change, and the overall size / shape remained

[14] This represented an approximately 50% change in terms of shared pixels, whereas a neutral to valenced face change represented approximately 10-15%.

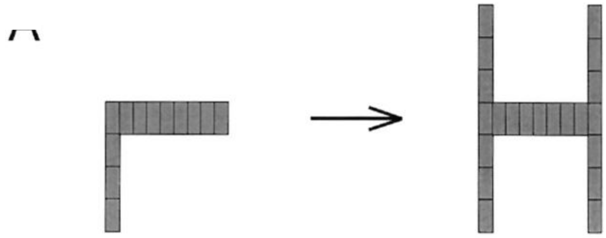

Figure 7.1 Right angled bracket changing into an H, with the onset of the full search array. (Reproduced with permission from Watson and Humphreys, 2002; Experiment 1).

constant). Based on this, one might expect that the types of changes in expression presented here would have minimal impact on the Preview Benefit.

Alternatively, even relatively small physical changes might be sufficient to abolish the Preview Benefit, if they result in a relatively high level change in the objects status. This would be as a result of the emotional content that they convey. In this respect, it might be predicted that the small physical changes in this instance, could be highly disruptive, because they result in a large change in the emotional status of the previewed objects. Moreover, if more weight is given to a *feature-based* processing view of facial schematics (e.g. Purcell & Stewart, 2006; see also Fox & Damjanovic, 2006; Tipples et al., 2002; for examples where specific regions of faces have been emphasized), the magnitude of the change to the mouth region alone (i.e. the stimulus feature most pertinent for the present search task), is more substantial, with approximately 90% change in terms of shared pixels for both expression valences.

In addition, these experiments aimed to examine any differential valence-based effects on the influence of stimulus change. For example, where an old face item changes to negative expression, would this alteration to facial affect represent a more behaviourally-relevant event than a change to a positive expression (i.e. in line with the negative superiority effect in search)? Or would the salience of any change to a face stimulus (or equally, any facial expression), serve to abolish the preview benefit; for example, demonstrating a general face relevance or *general emotionality effect*?

Previous work exploring the effects of negatively valenced faces in visual search (e.g., Eastwood et al., 2001; Fox et al., 2000; Öhman et al., 2001; Hansen & Hansen, 1988) suggests enhanced detection of (and potentially, preferential allocation of attention to) negative faces, which could subsequently impact on the ability to disengage from these stimuli and thus, overall search performance. However, the lack of valence-based differences in preview (at least, at the 1000ms preview duration, used in the standard paradigm) discussed above (see Chapter 5) means that predictions on the basis of valence effects are not straightforward to make in this instance. This presents the possibility that *any* change in facial expression is of high behavioural significance.

7.3 Experiment 10: Preview search with neutral to negative facial expression change

Experiment 10 examined the effect of a neutral to negative preview face expression change which occurred when the new items were added. This represented an additional level of ecological validity for the schematic faces used, but also reflected a behaviourally important change to the stimulus, that might impact on search performance.

7.4 Method

7.4.1 *Participants*

Eighteen students at the University of Warwick (12 female, 6 male) participated in this study for payment. Participants were aged between 18 and 24 years (*M*= 19.22 years), and all, but one, were right handed. All participants self-reported normal or corrected to normal vision.

7.4.2 *Stimuli and Apparatus*

A Gateway GP6 400 computer was used to present all displays and record participant responses in this and subsequent experiments. Stimuli were displayed on a 17 inch Gateway VX 700 monitor, with 800 x 600 pixels resolution and 75 hertz refresh rate, positioned at eye-level and at a viewing distance of approximately 60 cm. Stimuli were identical to those used in previous chapters, with similarity to those in a number of previous studies (i.e., Horstmann, 2007; Eastwood et al., 2001; Fox et al., 2000; White, 1995; Nothdurft, 1993).

All stimuli were drawn in light grey (RGB values = 200, 200, 200) against a black background. Targets consisted of positively valenced stimuli and all distractors had a neutral expression in their initial presentation. Distractors presented in the preview set showed neutral expressions for 1000ms and changed to a negative valence with the onset of the full search display (see Figure x). All face stimuli had a diameter of approximately 13 mm, subtending a visual angle of approximately 1.2°

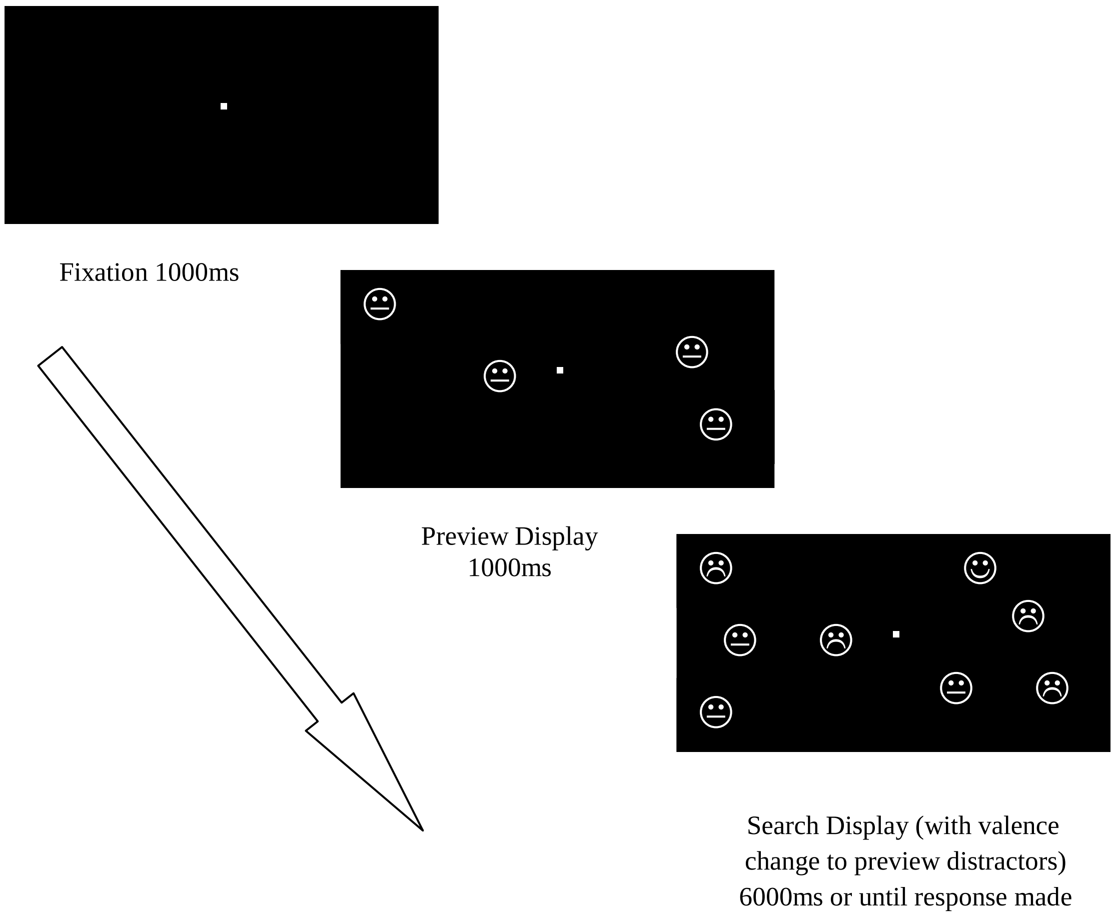

Figure 7.2 An example preview search trial with a positive target and a preview distractor change from neutral to positive facial expression (Experiment 10)

Search displays were generated by randomly positioning items within an invisible 6 x 6 matrix with an inter-element display spacing of 75 pixels. Stimulus positions were then jittered by up to +/- 4 pixels (approximately 29.25 mm) in both x and y axes. HEB displays consisted of display sizes of 2, 4, 6 and 8, divided equally between the right and left sides of the screen, with a positive target, when present, replacing one of the neutral distractors. This was displayed equally to the left or right of the midline.

Preview displays consisted of total display sizes of 4, 8, 12 and 16, with a positive target, when present, replacing a distractor. FEB trials also consisted of total display sizes of 4, 8, 12 and 16. However, in this latter case, the display comprised a mixture of negative and neutral faces (i.e., representing the final search array), with the search distractors (i.e. the neutral faces) decremented by one, when a target was present. On catch trials, no target face was present.

7.4.3 *Design and Procedure*

The experiment was conducted in a dimly lit, sound attenuated room and took approximately one hour to complete. The experiment was based on a 3 (Search Condition: HEB, FEB, Preview) x 4 (Display Size) within-subjects design. Each search condition was run in a separate block of 160 experimental trials[15] with a further 16 catch trials, where no target was present (see Chapters 4 and 5, for details).

[15] Due to programming error, the FEB condition contained a total of 176 trials, giving four extra trials per display size compared with other blocks. However, re-analysing the data, having removed the last 16 trials within each FEB block, produced statistically identical results.

When a target was presented, it was shown equally often to the right or left side of the screen. Targets were not presented in the centre two columns of the matrix (i.e., were only presented in columns 1, 2, 5 and 6), to ensure they could easily be distinguished from the midline of the display.

A trial in the HEB and FEB conditions consisted of a blank screen (1000 ms), followed by a light grey central fixation dot (2mm x 2mm) for 1000 ms, followed by the search display. The preview condition was similar, except that half of the distractors were presented for 1000ms before onset of the second display, which contained the target, when present. Participants were asked to locate a positively valenced face target and indicate whether it was to the left or the right of the display centre by pressing the Z or M key respectively, or to make no response if the target was absent. The fixation dot remained visible throughout the trial and participants were asked to remain fixated until the final search display appeared.

In the preview search condition, participants were instructed to ignore the first display (which contained distractors only) and to respond to the second display, which would contain the target, when present. Changes to the preview distractors were made concurrently with the onset of this second set. Participants were informed of the valence change to the preview distractor faces and when it would occur, but were asked to continue ignoring these stimuli to the best of their ability, despite the changes. In all conditions, the search display remained on screen until the participant responded, or for 6000 ms, after which the next trial began. If an error was made, or no response was given when a target was presented, feedback was given in the form of a short tone (1000 Hz, 500 ms).

7.5 Results

7.5.1 *Reaction time data*

All anticipatory RTs (i.e. < 150 ms) were discarded and treated as errors. Mean correct RTs were then calculated for each cell of the design individually for each participant. Overall mean correct RTs are shown in Figure 7.3, with search slopes statistics presented in Table 7.1. As in previous research on the preview benefit, search slopes were plotted and calculated using the same display sizes as for the FEB. This procedure gives the values that would be expected if observers were able to fully ignore the old items in the preview condition, and enables direct comparison of the preview condition with both baseline conditions (i.e. HEB and FEB). Full evaluation of performance in the preview condition was conducted via ANOVA for all search conditions and planned comparisons between conditions.

7.5.2 *HEB vs. FEB vs. Preview Condition*

Mean correct RTs were analyzed using a 3 (Condition) x 4 (Display Size) within-subjects ANOVA. There were highly significant main effects of Condition, $F(2,34)=93.01$, $MSE= 74866.84$, $p<.001$, Display Size, $F(3,51)= 349.41$, $MSE= 20413.70$, $p<.001$, and Condition x Display Size interaction, $F(6,102)= 36.08$, $MSE= 9649.60$, $p<.001$. Overall RTs were longest in the FEB and shortest in the

Table 7.1 Search slope statistics for Experiment 10, change from neutral to negative expression, by block type and preview duration

	Search Condition		
Slope Statistics	HEB	FEB	Preview
Slope (ms/item)	40.18	80.67	89.61
Intercept (ms)	541.36	739.50	470.66
R^2	1.00	0.98	1.00

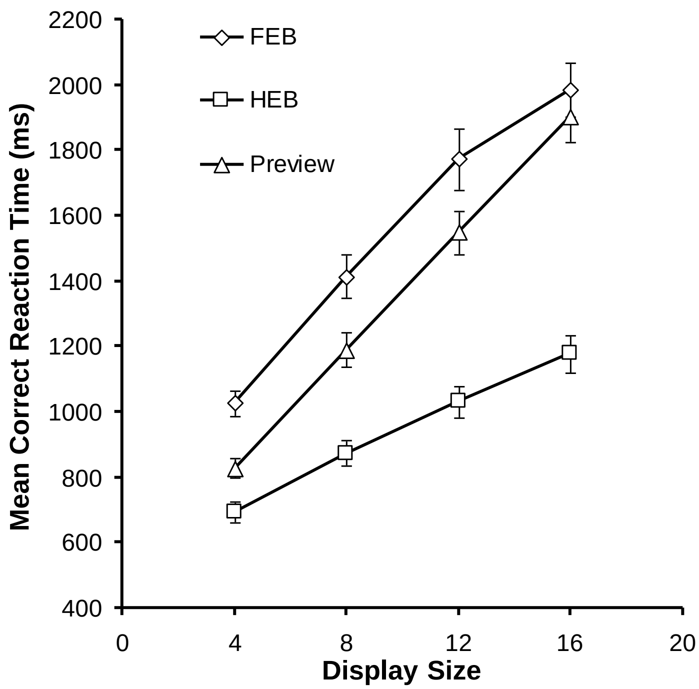

Figure 7.3 Mean correct RTs for ignoring a change from neutral to negative facial expression, as a function of condition and display size for Experiment 10. Error bars indicate ±1 standard error.

HEB, increased as display size increased, and were more efficient in the HEB than either the FEB or preview condition.

7.5.3 *HEB vs. FEB*

Both main effects proved highly statistically significant. RTs were faster overall in the HEB; Condition, $F(1,17)=206.77$, $MSE= 63983.62$, $p<.001$, increased with Display Size, $F(3,51)= 225.19$, $MSE= 15796.58$, $p<.001$. In addition, search efficiency was greater in the HEB, $F(3,51)= 60.05$, $MSE= 6946.62$, $p<.001$.

7.5.4 *HEB vs. Preview Condition*

Both main effects proved statistically significant. RTs were faster overall in the HEB; Condition, $F(1,17)=92.21$, $MSE= 70065.18$, $p<.001$, increased with Display Size, $F(3,51)= 296.35$, $MSE= 13647.12$, $p<.001$. In addition, search efficiency was greater in the HEB, $F(3,51)= 68.95$, $MSE= 8512.33$, $p<.001$.

7.5.5 *FEB vs. Preview Condition*

Again, both main effects proved significant. RTs were faster in the Preview Condition than in the FEB, $F(1,17)= 13.25$, $MSE=90551.71$, $p<.005$, and RTs increased as Display Size increased, $F(3,51)= 333.38$, $MSE= 21033.30$, $p<.001$. In addition, the Condition x Display Size interaction, $F(3,51)=3.00$, $MSE= 13489.85$, $p< .05$, also achieved statistical significance, showing greater search efficiency in the FEB.

7.5.6 *Error data*

Mean percentage errors are shown in Table 7.2. On search trials, errors were low overall (1.75%) and were logarithmically transformed in order to avoid

Table 7.2 Mean percentage error rates for Experiment 10, by search condition and display size

	Display Size				
	2	4	6	8	
	4	8	12	16	Mean
Search Trials					
HEB	0.97	0.97	1.39	1.11	1.11
FEB	1.39	1.26	2.53	3.66	2.21
Preview	0.83	0.97	1.25	2.36	1.35
Catch Trials					
HEB	18.06	2.78	6.94	2.78	7.64
FEB	6.94	5.56	5.56	2.78	5.21
Preview	6.94	2.78	2.78	6.94	4.86

compression issues. These transformed data were then analyzed with a 3 (Condition) x 4 (Display Size) within-participants ANOVA, which revealed significant main effects of Display Size, $F(3,51)= 3.18$, $MSE =0.09$, $p<.05$, and Condition, $F(2,34)=5.98$, $MSE= 0.11$, $p<.05$, with errors increasing with increasing items in the display, and with slower performance in the FEB, than either the HEB or Preview condition.

However, the Condition x Display Size interaction, $F(6,102)=1.52$, $MSE= 0.08$, $p= .18$, did not prove statistically reliable. Overall error rate on catch trials was also relatively low (5.61%). These data were also analyzed with a 3 (Condition) x 4 (Display Size) within-subjects ANOVA, both the effects of Display Size, $F(3,51)=3.67$, $MSE=152.00$, $p<.05$, and the Condition x Display Size interaction, $F(6,102)= 2.50$, $MSE= 107.74$, $p<.05$, proved significant. However, the main effect of Search Condition, $F(2,34)= 1.23$, $MSE= 134.29$, $p=.31$, failed to reach significance.

7.6 Discussion

Experiment 10 aimed to explore the effects of changes to preview distractors upon performance in preview search with facial stimuli. In particular, it evaluated the influence of a change from a preview containing faces with neutral facial expressions, to faces with negative expressions. The main finding was a clear disruption of the preview benefit. Typically, an efficiency advantage in preview search is evaluated by comparison of the search slope function of the Preview condition to those of the two baseline search conditions (i.e. the HEB and FEB). Here, the search slope function for the preview condition was less efficient than in the HEB and unusually, was also less efficient than in the FEB (89.6 ms/item preview vs. 80.7 ms/item FEB).

This abolition of the preview benefit is in line with previous findings that a behaviourally relevant change (i.e. comprising change to an object's shape or identity) disrupted the preview benefit (e.g., Watson & Humphreys, 2002, 2005; Watson et al., 2008). However, RT differences persisted (RTs were faster in the Preview condition than the FEB), despite the reversal of search efficiency between these conditions, demonstrated by comparison of the search slopes. This effect had not been demonstrated previously (i.e. where an overall RT advantage had been demonstrated in previous work; see Watson & Humphreys, 2002, 2005; Watson et al., 2008; this had also been accompanied by increased search efficiency in the Preview condition). Explanations for this effect are not particularly clear, but will be discussed below (Chapter 8).

7.7 Experiment 11: Preview Search with neutral to positive face stimulus change

Experiment 11 examined the effect of the opposite valence change (from neutral to positive). Following previous work showing that a change to an item shape or identity abolishes preview benefit (Watson & Humphreys, 1997, 2002), Experiment 10 above, showed a valence change to a face stimulus, when a neutral expression changed to a negative (sad) expression. This resulted in a disruption of preview advantage in terms of search efficiency, although an advantage in RT performance remained in the preview condition.

Thus, one might predict that a change from neutral to positive facial valence would affect preview benefit in a similar fashion. However, as negative valenced faces (and stimuli, in general) are reported to be particularly effective at capturing or guiding attention (e.g., Eastwood et al., 2001; Öhman et al., 2001; see Frischen et al., 2008), and therefore, might be seen as difficult to suppress, it does not necessarily follow that the opposite valence change will result in reduced preview benefit. It may be the case that a change to a positive expression will not disrupt performance in the preview condition, compared to that in the baseline conditions. This would be likely if a negative facial change is interpreted as more behaviourally relevant than a change to a positive expression, consistent with an adaptive ability to detect threat in the environment (i.e. Öhman & Mineka, 2001; LeDoux, 1996,1998).

In contrast, in previous work (see Chapter 5 above), no difference in preview benefit was observed between negatively and positively valenced faces previewed at this time duration (i.e. 1000 ms). Accordingly, one might expect that any change to a face preview will affect search performance in the same way, regardless of change valence (i.e. the *general emotionality effect*; see Fox et al., 2000; Martin, Williams & Clark, 1991; see also Compton, 2003; for further discussion of the behavioural importance of emotional events).

7.8 Method

7.8.1 *Participants*

Eighteen students at the University of Warwick (11 female, 7 male) participated in this study, either for payment or course credit. Participants were aged between 18 and 32 years (M=21.94 years), and all were right handed. All participants self-reported normal or corrected to normal vision.

7.8.2 *Stimuli and Apparatus*

All apparatus was identical to Experiment 10 above. Stimulus sets were highly similar to that experiment, except in that targets consisted of negative valenced stimuli, and all FEB trials consisted of mixed neutral and positive face distractor sets. In the preview condition, distractors changed from a neutral to a positive expression after 1000ms.

7.8.3 *Design and Procedure*

The design and procedure were identical to that described in Experiment 10 above, except for target valence and facial expression change. In this instance, the target was a negative face, and the change to preview distractors was from neutral to positive facial expression (occurring with the onset of the full search set). As before, participants were informed of all aspects of the preview change, prior to undertaking the preview practice and experimental blocks.

7.9 Results

7.9.1 *Reaction time data*

All anticipatory RTs (i.e.< 150 ms) were discarded and treated as errors. Mean correct RTs were then calculated for each cell of the design, for each participant individually. Overall mean correct RTs are shown in Figure 7.4 with search slopes statistics presented in Table 7.3. As outlined above, search slopes were plotted and calculated using the same display sizes as for the FEB, giving the values expected if observers were able to fully ignore the old items in the preview condition. This facilitated direct comparison of the preview condition with both baseline conditions (i.e. HEB and FEB). Full evaluation of performance in the preview condition was conducted via ANOVA for all search conditions and planned comparisons between conditions.

7.9.2 *HEB vs. FEB vs. Preview Condition*

Mean correct RTs were analyzed using a 3 (Condition) x 4 (Display Size) within-subjects ANOVA. There were highly significant main effects of Display Size, $F(3,51)=133.38$, $MSE= 15333.88$, $p<.001$, and Search Condition, $F(2,34)= 50.68$, $MSE= 63483.28$, $p<.001$. The Condition x Display Size interaction, $F(3,51)= 16.58$, $MSE= 6543.98$, $p<.001$, also proved highly significant. Overall RTs were longest in the FEB and shortest in the HEB, increased as display size increased, and were more efficient in the HEB than either the FEB or Preview condition.

7.9.3 *HEB vs. FEB*

Both main effects of Display Size, $F(3,51)= 98.19$, $MSE= 11590.64$, $p<.001$, and Search Condition, $F(1,17)= 112.90$, $MSE= 52659.94$, $p<.001$, proved highly significant, with RTs increasing as Display Size increased, and being faster in the HEB than in the FEB. In addition, the Condition x Display Size interaction, $F(3,51)=31.45$, $MSE= 5857.52$, $p<.001$, also reached high statistical significance, showing greater search efficiency in the HEB.

Table 7.3 Search slope statistics for Experiment 11, change from neutral to positive expression, by block type and preview duration

	Search Condition		
Slope Statistics	HEB	FEB	Preview
Slope (ms/item)	20.57	48.05	44.01
Intercept (ms)	530.64	662.20	600.38
R^2	0.96	1.00	0.99

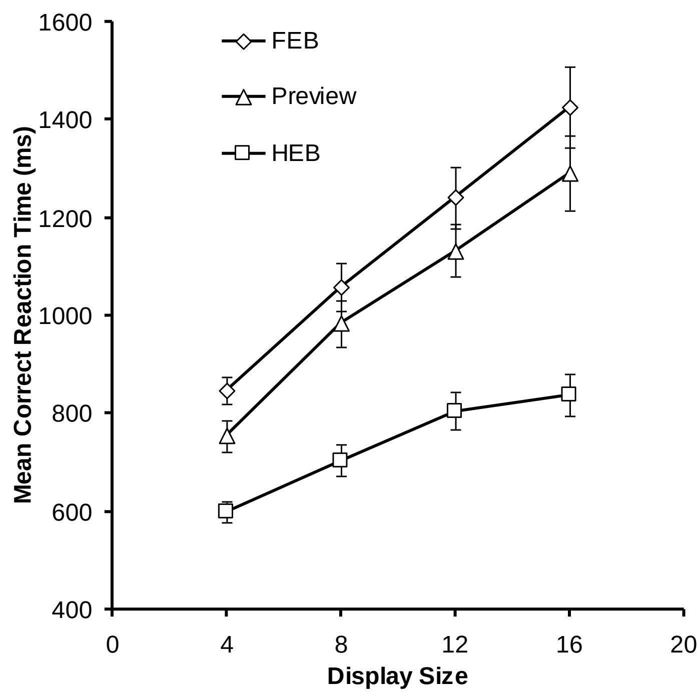

Figure 7.4 Mean correct RTs for ignoring a change from neutral to positive facial expression, as a function of condition and display size for Experiment 11. Error bars indicate ±1 standard error.

7.9.4 *HEB vs. Preview Condition*

Both main effects of Display Size, $F(3,51)= 103.12$, $MSE= 9863.37$, $p<.001$, and Search Condition, $F(1,17)= 83.18$, $MSE= 40040.04$, $p<.001$, proved highly significant, with RTs increasing as Display Size increased, and being faster in the HEB than in the Preview Condition. In addition, the Condition x Display Size interaction, $F(3,51)=33.09$, $MSE= 4092.46$, $p<.001$, also reached high statistical significance.

7.9.5 *FEB vs. Preview Condition*

The main effect of Display Size proved highly significant, $F(3,51)= 129.70$, $MSE= 15757.73$, $p<.001$, with RTs increasing as Display Size increased. In addition, there was a marginally significant effect of Condition, $F(1,17)= 3.85$, $MSE= 97749.86$, $p=.07$, with RTs were faster in the Preview Condition than in the FEB. However, the Condition x Display Size interaction, $F(3,51)=0.61$, $MSE= 9681.97$, $p= .61$, did not approach statistical significance.

7.9.6 *Error data*

Mean percentage errors are shown in Table 7.4. On search trials, errors were low overall (0.75 %) and, similarly to Experiment x above, were log transformed and then analyzed with a 3 (Condition) x 4 (Display Size) within-participants ANOVA. There was a significant effect of Display Size, $F(3,51)= 2.77$, $MSE =.07$, $p=.05$, with errors tending to increase with increasing items in the display . A significant main effect of Condition, $F(2,34)=6.46$, $MSE= .08$, $p<.005$,

Table 7.4 Mean percentage error rates for Experiment 11, by search condition and display size

	Display Size				
	2	4	6	8	
	4	8	12	16	Mean
Search Trials					
HEB	0.00	0.00	0.42	0.83	0.31
FEB	0.42	0.97	1.25	1.39	1.01
Preview	0.83	0.83	1.11	0.97	0.94
Catch Trials					
HEB	15.28	4.17	0.00	4.17	5.90
FEB	2.78	1.39	2.78	2.78	2.43
Preview	5.56	1.39	1.39	1.39	2.43

indicated that more errors were made in the FEB and Preview conditions, than the HEB. The Condition x Display Size interaction, $F(6,102)= 0.37$, $MSE= 0.05$, $p=.90$, did not approach significance.

Overall error rate on catch trials was 3.59 %. These data were also analyzed with a 3 (Condition) x 4 (Display Size) within-subjects ANOVA. In this instance, the main effect of Display Size, $F(3,51)=3.44$, $MSE= 133.39$, $p< .05$, was statistically significant, with particularly high error rates observed in the smallest display size. In addition, there was a significant Condition x Display Size interaction, $F(6,102)= 2.30$, $MSE= 87.26$, $p<.0.5$. However, the effect of Search Condition, $F(2,34)= 3.21$, MSE= 90.21, p=.05, achieved only marginal significance, with a trend towards higher percentage errors in the HEB, than either FEB or Preview condition. In turn, this latter marginal effect may have driven the significant Condition x Display Size interaction.

7.10 Discussion

Experiment 11 explored further the effects of changes to preview distractors on search performance, with the previewed neutral schematic faces, changing to a positive expression (i.e. happy faces). The most important question here were whether this change of expression in previewed faces (i.e. neutral to positive affect) disrupted the preview benefit. Similarly to Experiment 10 above, the main finding was a clear disruption of preview benefit, again with the effect demonstrated in measures of search efficiency. In this instance, there was no robust difference in overall RT, nor improved search efficiency in the Preview condition when compared with the FEB. Search efficiency was impaired in the Preview condition, relative to the HEB.

7.11 Comparison between Experiment 10 and 11

As in Chapter 5 above, a simple between-experiment comparison is not appropriate in this instance. This is due to the baseline search slopes differing between the experiments as the overall effect of target valence on search persists (i.e. negative targets are detected more rapidly, even in standard visual search conditions). Accordingly, measures of preview search efficiency (PE) that were calculated, independent of the overall baseline search rates (see Chapter 5, Experiments 5, 6 & 7; for previous use of this evaluation). Two measures of preview search efficiency were calculated, one based on overall RTs ($PE_{overall}$) (1), and the other based on search slopes (PE_{slope}) (2). These measures were determined by calculating the difference between the FEB and preview search conditions, divided by the difference between the FEB and HEB search conditions for each individual participant[16], for both Experiments 10 and 11.

$$PE_{overall} = \frac{FEB_{overall} - PRE_{overall}}{FEB_{overall} - HEB_{overall}} \qquad (1)$$

$$PE_{slope} = \frac{FEB_{slope} - PRE_{slope}}{FEB_{slope} - HEB_{slope}} \qquad (2)$$

[16] In instances where the HEB value exceeded that of the FEB, that case was excluded from the analysis.

Calculated this way, as preview search becomes more efficient, PE tends towards 1, and as it becomes less efficient, it tends towards 0, with calculations bounded by 0 and 1.

In terms of search slopes, preview benefit was numerically larger where previewed neutral faces changed to positive faces (i.e. Experiment 11) than where preview faces changed to negative faces (i.e. Experiment 10), ($PE_{positive}$ =0.27 ; $PE_{negative}$=0.11). However, this difference was not reliable, $t(34)= 1.77$, $p = .09$. Similarly, There were no differences in terms of overall RTs, ($PE_{positive}$ = 0.30; $PE_{negative}$=0.33), $t(34)=0.36$, $p= .72$. This analysis showed no evidence of a differential preview benefit across experiments in either measure of preview efficiency.

In this way, it is possible to suggest that performance differences, where a previewed neutral face changes to either a negatively or positively valenced face, are negligible; both present circumstances where the behavioural relevance of the change is sufficient to disrupt preview benefit. More importantly, it is possible to say that change to facial expression, regardless of emotional valence, abolishes the ability to ignore previewed faces.

Chapter 8

Conclusions

(Part of this chapter is adapted from the paper "Visual marking and facial affect: Can an emotional face be ignored?" accepted for publication in *Emotion*.)

8 Conclusions

8.1 Aims of this thesis

In brief, given the behavioural importance of faces and their affective content, it is difficult to refute the value of i) exploring the parameters of attentional processing in respect of facial stimuli and ii) understanding the impact these attentional properties might have on cognition and social behaviour. Furthermore, as previous work has highlighted the adaptive nature of any mechanism that facilitates differential processing of valenced faces (i.e. those that indicate potential threat to the observer, and those that do not), it is also important to evaluate these attentional properties in terms of the real world. Attempting to bridge the gap between controlled experimental investigation and findings that apply beyond the laboratory is crucial to investigating human behaviour in a meaningful way.

The research questions underpinning the investigations here have emerged from this standpoint. Using the preview search paradigm, in which (according to Watson & Humphreys, 1997; 1998) effective search performance relies on the ability to inhibit old items, in order to prioritize new items in the visual field, this thesis has investigated the following questions:

1) Is it possible to ignore faces (as schematic representations)?
2) Do positively and negatively valenced face previews elicit differential processing in circumstances of temporal selection?

3) Are there performances differences in visual search with valenced schematic faces when participants have prior knowledge of target identity (compared with when then do not)?
4) Are effects of differential processing evident in early temporal selection (i.e. when preview duration is shortened)?
5) Can valenced face previews be fully ignored, given sufficiently long preview durations?
6) Does a change to a facial expression affect performance in preview search with schematic faces?
7) If preview search is affected by an expression change, does this vary on the basis of valence?
8) Does the well-documented search advantage for negatively valenced facial stimuli persist in conditions of temporal selection?

The remainder of this chapter will attempt to answer these questions; summarizing the findings from each chapter, discussing them in the context of the background literature, and finally, addressing their implications for future research.

8.2 Summary of main findings

The overarching aim of this thesis was to examine time-based visual selection using schematic face stimuli that show neutral, negative or positive affect. Although these stimuli had been evaluated previously, in terms of spatial selection (i.e. via the visual search paradigm; e.g., Eastwood et al., 2001; Öhman et al., 2001; Fox et al., 2000; see Frischen et al., 2008; Horstmann, 2009; for extensive reviews), their use in other paradigms has been limited. Despite some ambiguity in the literature (e.g., Williams et al., 2005b; Juth et al., 2005), it is widely held that negative faces, in general, guide attention more efficiently to themselves amongst distractor sets of neutral or positive faces, than the reverse. In addition, evidence from flanker (Fenske & Eastwood, 2003; Horstmann, Borgstedt, & Heumann, 2006) and cueing studies (Fox et al., 2001, 2002; Georgiou et al., 2005) indicated that visual attention was also held more efficiently at locations of negatively valenced faces, consistent with impairment of attentional disengagement from these stimuli. Thus, it might have been predicted that faces, and negatively valenced faces in particular, would be difficult to intentionally suppress (i.e. given their attentional properties and behavioural relevance).

Reviewing the findings of the previous empirical chapters (Chapters 4-7); the first important finding (Experiment 3) was that it *is*, in fact, possible to ignore face stimuli. In this instance, the preview displays consisted of emotionally neutral schematics, and the subsequent search display comprised both neutral schematics and a valenced target; either negative or positive. In this experiment, only a partial preview benefit was demonstrated. In addition, a search advantage was clearly demonstrated for detection of the negative face target.

Subsequent experiments in Chapter 5 (Experiments 5-7) also demonstrated a search advantage for detecting negative face targets, amongst either homogenous (neutral) or heterogeneous distractor sets (neutral and positive), in comparison to the reverse. This was evident in circumstances of spatial selection (visual search), with and without prior knowledge of target valence (Experiment 4), and temporal selection (preview search), where preview displays consisted of valenced faces, either positively or negatively valenced faces. The latter experiments examining temporal selection (i.e. preview search using valenced previews) were conducted using both between- and within-participants designs, although this change in design affected the results little (see Experiments 5, 6 and 7).

However, most importantly, although a robust partial preview benefit (similar to that seen in Experiment 3) persisted throughout these experiments, two distinctive findings emerged. Firstly, at no point was a full preview benefit obtained using a face preview (in this case, a valenced face preview). And secondly, there was no reliable evidence of differential processing according to the valence of the faces which were previewed by the observer. This latter finding held even when the power of the between-participants analysis was increased by a within-participants design and an increased sample size. In view of the widely-accepted attentional properties of negatively valenced faces (i.e. that they effectively attract *and* hold visual attention; see Chapter 3 above), the absence of differential valence-based processing here was surprising.

Expanding the preview search paradigm by systematically varying the duration of the preview (recall that the typical preview duration is 1000 ms; e.g., Watson & Humphreys, 1997, 1998), meant it was possible to investigate whether valence effects lay elsewhere in temporal selection processing. This was particularly relevant, given that differentiation between valenced stimuli (e.g., Smith et al., 2003) appears to emerge in early processing (i.e. at latencies of approximately 80 to 100 ms). Conversely, with the behavioural relevance of the valenced face, and potentially adaptive reasons for not being able to ignore facial stimuli, it was also possible that the standard 1s preview duration did not allow sufficient time for valence-based differences to be demonstrated.

This would be possible if negative valence affects the ability to effectively disengage from facial stimuli. Lastly, an extended preview duration (from 1000ms, to 2000 and 3000ms) might support a full preview benefit, as has been shown with other stimuli that have proved resistant to suppression (Braithwaite et al., 2006).

When the preview duration was shortened to 250, 500 and 750 ms (in Experiments 8a and 8b), clear differential valence-based processing was evident. Whereas positively valenced face previews could be effectively ignored from the shortest preview duration (250ms), negatively valenced face previews showed impaired performance at short preview durations (250-500ms), and did not achieve an effective preview benefit until the duration reached 750ms. Between 750 and 1000ms, valence-based differences in preview performance dissipated.

However, when preview duration was extended (from 1000 to 3000ms; Experiments 9a and 9b), there was no evidence of differential processing for negatively and positively valenced previews. Moreover, in more general terms, additional preview time did not enable observers to fully inhibit either valence preview; a partial preview benefit persisted throughout both the extended previews and the truncated positive face preview (Experiments 8 and 9). The search advantage for negative faces was also evident throughout all experiments in Chapter 6.

Lastly, in Chapter 7, the effects of a change to facial valence to previewed faces were evaluated. This added a dimension of increased ecological validity to the displays used, in that, facial expressions in the visual environment rarely remain static for any period of time; *some* dynamic element is usually present in facial displays. In the context of previous work examining the effects of change to previewed items (Watson &

Humphreys, 2002, 2005; Watson, Humphreys, & Braithwaite, 2008), only alterations that represented a behaviourally relevant change (for example, to shape or object identity) would be expected to disrupt the preview benefit. In Experiments 10 and 11, clear evidence of disrupted preview was displayed, but without reliable support for differential effects of valence.

This was surprising on two counts; firstly, previous work had relied upon substantial physical changes to the previewed stimuli, notwithstanding the nature of the change. Secondly, given the potentially adaptive mechanism believed to drive the search advantage for negative faces (e.g., Öhman et al., 2001), it would appear likely that a change from neutral to negative expression would be of more adaptive importance than a change to a positive expression; thus the lack of difference was unexpected.

Thus, the main findings of this thesis can be summarized: First, a robust, but not full, preview benefit was obtained when ignoring face stimuli (Experiments 3 to 7), which held even when the preview duration was extended up to 3s (Experiment 9) and applied equally to valenced and non-valenced faces. Second, a negative target face search advantage remained during time-based selection conditions, irrespective of whether or not the valence of the target was known in advance (Experiments 3-11). Third, ignoring negative faces took longer than ignoring positive faces, but this difference had dissipated by approximately 750-1000 ms (Experiment 8). And fourth, an expression change to a previewed face disrupted the preview benefit, but with no reliable impact of the valence of the change (Experiments 10 and 11).

The implications of these findings are discussed in more detail below.

8.3 Theoretical implications of these findings

8.3.1 *Ignoring face stimuli*

An important question from the start of this thesis was, whether it is possible to intentionally ignore face stimuli at all, given their salience and behavioral relevance? It was possible that the suppressive mechanism proposed to account for the preview benefit (Watson & Humphreys, 1997) would be sufficiently strong to effectively exclude face stimuli. This would mean that intentional, top-down, inhibition of these stimuli would be clearly demonstrated, and thus, able to override the attention attracting properties of faces in general (see Palermo & Rhodes, 2007; Frischen et al., 2008; Hortsmann, 2009; for comprehensive reviews). The implications here for mechanisms of cognitive flexibility would be substantial. However, the alternative was that if the mechanisms underlying the preview benefit are sensitive to ecological constraints (see Watson & Humphreys, 2002; Watson, Braithwaite & Humphreys, 2008), then faces might be relatively difficult to suppress. In this case, it would be possible to propose a highly adaptive function associated with this facet of face processing, albeit one that constrained the ability to intentionally manipulate processing of the visual environment.

Throughout Experiments 3- 7, a robust but partial preview benefit was found consistently (note that any valence-based effects will be considered separately, below). This suggests that, compared with the more abstract stimuli used in previous studies of time-based selection (e.g. Watson & Humphreys, 1997; 1998), faces may be generally more difficult to ignore. Moreover, this result meshes with previous work highlighting the importance of faces to our social functioning (Carey, 1992) and their salience in the visual field. Indeed, evidence suggests that the mere presence of faces demands allocation of processing resources (Lavie et al., 2003), and it is possible that this may play a role in some of the evidence of delayed disengagement from face stimuli (Fox et al., 2001, 2002; Georgiou et al., 2005). In other words, the relatively impaired preview benefit may derive from the fact that faces are simply too important to be able to ignore fully (see also Palermo and Rhodes, 2007; Compton, 2003; for further discussion of face-specific and general emotional impact on attentional processing). In addition, the potentially automatic allocation of attention to faces might result in reduced resources being available for suppressing the preview stimuli, thus leading to a reduced preview benefit (see below).

Moreover, the fact that observers are unable to ignore faces completely, even when preview duration was extended up to 3000 ms lends support to this argument. This result contrasts with previous work showing that stimuli resistant to suppression at a 1000ms preview (e.g., those isoluminant with their background, Braithwaite et al., 2006) could elicit a full preview benefit, when given sufficient time to suppress them.
Thus it may be possible that, in the case of facial stimuli, some property other than simply being “resistant to suppression” is operating; the findings of Braithwaite and colleagues (2006) indicate that it is possible to override such resistance, if adequate time for processing is given.

In fact, in their study, Braithwaite et al., (2006) attribute the additional time needed to suppress the isoluminant stimuli to the difficulty in localizing the stimuli, prior to encoding. This is unlikely to impact in this instance, given the attentional properties of facial stimuli (i.e. their ability to capture attention, and general perceptual salience). Thus, this highlights both the potency of the face within human visual processing, and the fact that, whatever mechanisms underlie the operation of the preview benefit, they are likely to be sensitive to the ecological context and the adaptive nature of any processing consequences.

Interestingly however, this general result differs from a recent finding in which previewed face stimuli were used. Allen, Humphreys and Matthews (2008) presented observers with a preview consisting of blue tinted faces, followed by the addition of new red house distractors and a blue house target. In contrast to the evidence above (Experiments 3-7), a statistically full preview benefit was obtained in Allen and colleagues' preview search condition, indicating that those faces could be fully suppressed (e.g., the preview condition did not differ from the HEB). One possibility for this difference in findings is that in the Allen et al., (2008) study, participants might have been able to suppress the blue previewed faces more effectively, on the basis of their colour (see Braithwaite, Humphreys & Hodsoll, 2003, 2004; Braithwaite et al, 2007).

This would also be consistent with Watson, Braithwaite & Humphreys' (2008) recent study, where they showed that colour differences between old and new items could be used in preview search conditions to reduce the effects of large luminance changes in the old items (compared to monochromatic old and new items). However, if colour based inhibition were playing a role, then we might expect the inhibition to carry over to the new target sharing the colour of the previewed faces (blue). This would make its detection particularly inefficient; reducing or abolishing any preview benefit (Braithwaite et al., 2003). Alternatively, Allen et al.'s full preview benefit might have been attributable to a lack of power in their design. Indeed, their search was substantially less efficient numerically in their preview condition (11.5ms/item) than in their associated half element baseline (-6ms/item), with a condition x display size interaction that approached significance, *p*=.08.

8.3.2 *The effects of stimulus valence on performance in preview search*

Another principle focus of this thesis was to determine whether facial valence influences the ability to intentionally ignore faces presented in a preview. The rationale behind this emphasis rested upon a well-established finding in the visual search with faces literature (e.g., Eastwood et al., 2001; Fox et al., 2000; Öhman et al., 2001; see Frischen et al., 2008; Horstmann, 2009; for reviews). This can be summarized as a general search advantage for negatively valenced face targets (i.e. those with angry, sad or fearful expressions) when presented amongst neutral or positively valenced distractor faces. Note that, in contrast to a more "typical" search advantage for negative faces, where the target's ability to guide attention effectively to itself is examined, the *preview search* paradigm relies on successful de-prioritization (or ignoring) of the previewed faces. Moreover, in the context of preview search, it is not possible to dissociate the effects of valenced targets and valenced distractor sets; it is likely that both impact on the overall search performance (see Eastwood et al., 2001, for further discussion of this point). However here, the focus rests on the attentional properties of the faces themselves, rather than emphasizing that distinction. The section below (discussing the implications for further work) will return to this point.

There are two aspects of the literature that could potentially impact here. Reasoning that if negative stimuli are particularly potent within the attentional system (e.g., LeDoux, 1996; Öhman & Mineka, 2001) , then they might be much more difficult to ignore than positively valenced stimuli, it was possible that this would result in a diminished or abolished preview benefit when compared with when a preview display comprised positive faces. This would strengthen any suggestion that the negative face search advantage is adaptive in nature, preventing the visual system from de-prioritizing this type of stimulus, regardless of the observer's intention (and task-relevant top-down input).

Alternatively, it is also possible that faces showing any emotion per se (compared to a neutral expression), are more difficult to ignore as a general class of stimuli (see Fox et al., 2000; Martin et al., 1991; *general emotionality hypothesis*; see also Compton, 2003). Whilst this might appear less likely, given the weight of evidence for a negative valence/ threat superiority with faces, there is *some* debate within the visual search with faces literature. And it is possible that a general salience of any facial affect could play a role where the search advantage has not been demonstrated (e.g., Compton, 2003). In any event, it is useful to consider the effects of *any type* of facial affect in addition to, or at least in parallel to, the general attentional properties attributed to the face, although obviously, it is difficult to separate the two.

In terms of this thesis, the effects of valence were relatively clear. The results of Experiments 5 to 7 in Chapter 5,- in which the old (valenced) stimuli were previewed for 1000ms- were straightforward; ignoring valenced stimuli produced a partial preview benefit (as was the case for ignoring neutral faces). That said, there was no difference in the efficiency of ignoring negative compared with positive faces. This was surprising, at first glance, seeing as negatively valenced faces have been suggested as both drawing *and* holding visual attention more effectively than other valenced faces (i.e. neutral or positive), when presented in a number of attentional paradigms (such as visual search, cueing or flanker tasks; e.g., Eastwood et al., 2001; Fox et al., 2000, 2001, 2002; Georgiou et al., 2005; Fenske & Eastwood, 2003; Horstmann et al., 2006)

However crucially, recall that when preview duration was reduced from 1000ms (as per the standard preview search paradigm) to 250, 500 and 750 ms, differential processing of negative and positive faces was demonstrated clearly (Experiment 8). Whilst ignoring positive face previews was consistently efficient from the shortest preview duration to the longest, efficiency was significantly hampered at the shortest preview durations for negative face previews, and did not approach optimum performance until approximately 750ms. Clearly, this gives a particularly striking example of differential processing, according to preview valence. Section 8.3.3 below focuses on potential explanations for these effects, which can be held as consistent with a number of theoretical perspectives (e.g., differentiation of negative and positive stimuli at short latencies; Smith et al., 2003; impaired disengagement with negative faces; Fox et al., 2001; Georgiou et al., 2005).

In contrast, when preview duration was extended from 1000- 3000ms, this did not affect the relative efficiency of ignoring either negative or positive faces, either within- or between-valence. In both instances, only a partial preview benefit was demonstrated. Thus, these findings support the notion that faces, whether valenced (or neutral), cannot be fully ignored, even if we allow additional time for this function, and more importantly, that the impact of valence-based differences has dissipated by this point in the processing stream (i.e. from 1000ms onwards).

That said, given the social importance attached to the face and its potential for communicating behavioral intention, this inability to extinguish the face's hold over attentional resources, regardless of valence, should still be considered adaptive (see also Watson & Humphreys, 2002; Watson, Braithwaite & Humphreys, 2008). This stands, even when considered alongside the impact on top-down cognitive flexibility. Moreover, it suggests that any further evaluative processing needed to establish threat to the observer, may have been undertaken by 750-1000 ms post stimulus onset, and from this time point onwards, the social relevance of *any* emotional face becomes equivalent, in terms of being able to fully suppress the stimuli.

In summary, valence has little differential impact on preview performance, other than at short preview durations (i.e. 250-750ms), when negative faces are more difficult to suppress than positive faces. However, this does not negate the fact that the behavioural importance or inherent emotional impact of the face stimulus per se (e.g., Compton, 2003; Palermo & Rhodes, 2007) or the generality of any facial emotion (i.e. Fox et al., 2000; Martin et al., 1991) may have prevented their complete suppression within preview search.

8.3.3 *Why are negative faces more difficult to intentionally suppress?*

Notwithstanding the absence of valence-based differential processing in the standard preview search paradigm (i.e. with a 1s preview), the finding that negative faces are more difficult to ignore at short preview durations is still consistent with many aspects of previous studies examining the effects of negatively valenced faces. For example, evidence that differentiation of negative and positive stimuli occurs at very short latencies (Smith et al, 2003), and that attention is allocated rapidly to face stimuli (Eimer & Holmes, 2002, 2007) might lead us to expect that differences between valenced faces would be most likely to be demonstrated early in their processing.

Potentially, this time course could also suggest the involvement of subcortical face processing (e.g. Johnson, 2005), given the rapidity of this pathway, and the involvement of subcortical structures in both face and threat detection (e.g., the amygdala; Hairiri et al., 2002; Whalen et al., 2004; Whalen et al., 1998).

Moreover, this might be considered even more pertinent in light of evidence from cueing studies (Fox et al., 2001), where negatively valenced schematic faces have elicited delayed disengagement at comparable latencies (i.e. approximately 250 – 300 ms post stimulus onset) to the preview durations used in Chapter 6 (Experiment 8; 250-750ms). In fact, given that the mechanisms believed to account for preview benefit (i.e. the top-down, inhibitory *visual marking* mechanism; Watson & Humphreys, 1997, 1998), similar findings in an attentional paradigm relying on effective disengagement from an affective face lend strong support to the ecological sensitivity proposed by Watson and Humphreys (2002, 2005; see also Watson, et al., 2008) in their account. It is possible that this should be considered to have an additive effect to the adaptive mechanisms suggested for processing threatening faces (i.e. LeDoux, 1996, 1998; Öhman & Mineka, 2001).

In addition, this finding may also be considered alongside much of the literature exploring visual search for emotional faces, in that we would expect negative faces to capture and hold attention, in preference to positive faces (e.g., Hansen & Hansen, 1988; Hampton et al., 1989; Öhman et al., 2001; Eastwood et al., 2001). This is clearly demonstrated in preview search, at least at preview durations shorter than those typically used to date (i.e. 1000 ms).

If we accept that, a broad discrimination between positive and negative valenced face stimuli may be made as early as 100ms post-onset (Smith et al., 2003), why should negative face stimuli require a longer preview duration to reach, in relative terms, their optimum preview benefit? As evidence suggests (Wagner, MacDonald, & Manstead, 1986; Russell, 1997; and see Russell, 1994, for a review) that it is more difficult for humans to distinguish between negative basic expressions (e.g., sadness, anger or fear), than to make a broad negative versus positive discrimination, it is possible that attentional resources are engaged in these stimuli until such further evaluation can be undertaken and a realistic assessment of threat can be made. This might consist of, for example, determining whether the facial expression indicates danger elsewhere in the environment (i.e. a fearful expression; see Williams et al., 2005b), that the threat is aimed at another (i.e. Von Grünau & Anston, 2005), or just categorizing the expression (where the expression is ambiguous; see Whalen et al., 1998).

In this case, it may be that active top-down suppression of negative stimuli (i.e. *visual marking*, Watson & Humphreys, 1997) might simply take longer to initiate, effectively having to wait until resources are released from processing the negative stimuli. This would be particularly relevant in the case of visual marking, as one aspect of the mechanism is believed to be capacity limitation (e.g., Watson & Humphreys, 1997; and see Chapter 2 above).

Note that this possibility is supported by previous findings showing that, when available attentional resources are reduced during preview search, via competing tasks (Watson & Humphreys, 1997; Humphreys, Watson & Jolicoeur, 2002) or stimuli (Kunar, Humphreys, Smith & Watson, 2003), a reduced preview benefit is demonstrated. Alternatively, the resources needed to inhibit the negative faces may actually be reduced initially, as the negative stimuli may automatically draw attention to themselves (e.g., Vuilleumier et al., 2001; Hansen & Hansen, 1988; Mogg & Bradley, 1999; Eastwood et al., 2003). Although the search rates demonstrated throughout the experiments in this thesis are not consistent with criteria generally held to indicate automatic, capacity-free or parallel processing (See Chapter 2, and Wolfe 1998 for a comprehensive review), loosely comparable searches in the literature have demonstrated search efficiency that fulfills this criteria (e.g., Hansen & Hansen, 1988; White, 1995; see Frischen et al., 2008; Horstmann 2007, 2009; and Chapter 3 above, for reviews).

Another possibility is that negative faces provide a more powerful signal for the attentional system, which simply takes longer to suppress to some minimum level than the signal associated with positive or neutral stimuli (but cf. Compton, 2003). Arguably, one could suggest that this is the case in some studies where a processing advantage has been found for positive faces (e.g., Kirita & Endo, 1995; Leppänen, & Hietanen; 2004; Leppänen, Tenhunen, & Hietanen, 2003). In these instances, the task demands (either through an attempt to dissociate the observer from the valence of the facial stimuli; i.e. by evaluating an unrelated feature; or through the focus of the paradigm; i.e. explicit recognition of the facial expression) effectively make the experimental task one of categorization rather than detection/search. For example, this could be where a participant is asked to make a judgment based on the perceived gender of faces presented, rather than the facial expression. Presumably, in these circumstances, it would take longer to suppress the attentional effects of any negative faces present, in order to undertake that processing; whereas processing resources would be released earlier from positive faces, enabling more rapid task completion.

In each of these events, this would result in a reduction of the speed at which the old negative stimuli would be suppressed. It is not clear at this point how convincingly these explanations might account for the data individually or in combination – indeed, the above accounts need not be mutually exclusive. However, differentiating between them, or establishing their relative contributions, is not possible using the methodology presented in this thesis. That said, it would be relatively straightforward to explore this issue via minor alterations to the experimental design and stimulus sets. This possibility is discussed in further detail below (see *Implications for future work* below).

8.3.4 *A caveat: Negative valence versus threat detection*

One aspect of the debate regarding negatively valenced stimuli that has not been addressed empirically in the chapters above (but, see Chapter 3), is the issue of "not all negative faces being created equal". That is, the possibility that negative facial expressions should not be considered as a homogenous group, and that there may be some variability in the valence-based effects they elicit, or the extent thereof (e.g., Öhman et al., 2001; Fox et al., 2000; Williams et al., 2005). In Chapters 4-7, negative (sad) faces have been detected more rapidly compared with positive targets. However, their negative valence appears to have had little reliable impact on how effectively they can be ignored when presented in a preview of longer than 750ms duration (see Experiment 5,6,7 and 9), or when a neutral facial expression changed to a positively or negatively valenced one (Experiments 10 and 11). Thus, it is possible that sad faces have less of valence-based impact upon attentional processing than angry or fearful faces, certainly in the preview search paradigm.

Given that there is evidence of differential processing prior to 750ms (i.e. with a preview duration between 250-750 ms), it is possible that all negative valence relevant processing has been undergone by this point, and any residual impairment of performance in the preview condition (i.e. a partial, rather than full preview benefit) is could be attributable to a general emotionality effect (see Martin et al., 1991). This would mean that where any face displaying affect (no matter which valence) is presented, it could be designated as behaviourally relevant without further differentiation between valence. In this particular instance, this is presumably because any rapid positive/negative differentiation has already been made, and further processing (for example categorizing the emotional expression) is not necessary or task-relevant.

Alternatively, we could question a generalized effect of stimulus negativity; for example, Öhman et al., (2001) proposed a distinction between threatening (i.e. angry, fearful) and non-threatening facial expression, when they found that an angry schematic face was located more rapidly than a sad one. This distinction has been supported by subsequent studies that fail to show a performance advantage for detecting a sad target, but do with a more threatening face target (e.g., Georgiou et al., 2005; Williams et al., 2005b). This may be due to the enhanced adaptive relevance of these stimuli (via a specialized neural and behavioural module dedicated to threatening stimuli; Öhman & Mineka, 2001; LeDoux, 1998, 1996; or biological preparedness to respond to fear-relevant stimuli; Seligman, 1970, 1971). Arguably, we could even propose that faces with increased threat relevance provide a more powerful signal to the neural architecture processing these stimuli, and thus, where the effects of "weaker" negative faces attenuate or dissipate completely, a stronger threat will continue to dominate the processing stream.

It is not possible to examine the comparability of negative (or threatening) expressions within the remit of these experiments. However, it may be feasible to do so in further work; although, this is somewhat limited by the flexibility of the schematic face (see Chapter 3 and below, for further discussion). It is possible that this question is best addressed by using more nuanced (and possibly, more ecologically valid) facial stimuli, e.g., photographic faces.

8.3.5 *Increasing ecological application: Expression changes in previewed faces*

In terms of human social interaction, faces rarely provide a single, unchanging stream of information where communication and behavioural intention meet. In fact, capturing a face in static pose is described by some as largely artificial (see Russell, 1994 for a review; and Chapters 1 and 3 above), and according to their perspective, casts doubt on the validity if evaluating facial expression thus. Overall, it is not difficult to assert that faces rarely provide a non-dynamic input for the visual system. And in turn, this means it is important to explore the boundaries of their attentional properties in a way that reflects the psychological reality. Examining the effects of an expression change to previewed faces is a first step towards this goal.

Experiments 10 and 11 demonstrated that a change in facial expression to previewed faces (i.e. from a neutrally valenced expression to a positive or negatively valenced one) abolished the search advantage gained in the preview condition. Although this was not entirely unsurprising, in that, previous work (i.e. Watson &

Humphreys, 2002, 2005; Watson et al., 2008) suggested that alterations to stimuli that present some kind of behaviourally-relevant change disrupt the preview benefit (i.e. changes to shape or object identity); there are aspects of these findings that bear closer examination. However, the absence of valence-based effects was particularly surprising, especially since negative faces have been detected more rapidly throughout Chapters 4-7.

8.3.6 *Changes to shape and object identity*

The disruption of preview benefit, here, was possible on two counts. Firstly, given the importance of any change to facial stimulus, in terms of behavioural relevance, this was likely to have an impact on suppression of previewed stimuli. Secondly, previous work (i.e. Watson & Humphreys, 2002, 2005; Watson et al., 2008) had indicated that changes to shape and high-level object identity disrupted preview benefit. Leaving aside any issue of attentional properties associated with affect or “faceness”, the change made to previewed faces constituted one that effectively created a new object. And, in this respect alone, one would predict that this “new object” would re-compete for attention following the onset of the full search array. Moreover, considering the adaptiveness of being able to detect such a change (i.e. when a conspecific’s intentions towards you are likely to become a threat), this finding was not unexpected.

However, in terms of previous work examining change to previewed items (e.g., Watson & Humphreys, 2002; 2005; Watson et al., 2008), the changes made to each individual facial stimulus were very small. For example, Watson & Humphreys (2002) made their *high-level object identity change* by changing a right angled bracket into a letter H, effectively doubling the number of pixels used in each stimulus. In contrast, in

Chapter 7, a small number of pixels deviated from a straight line neutral mouth in previewed faces, to curved one (i.e. either a “happy” or “sad” mouth) with the expression change (between 2-6 pixels). It appears unlikely that these physical changes are comparable to those described in previous work.

That said, it is possible that the additional attentional properties attributed to both the face, in general, and a valenced face, in particular, accentuate this small change. Alternatively, it may be that, given the weak inhibition of visually marked faces (i.e. in Chapter 5), any physical change is sufficient to disrupt the preview benefit. Either way, this disruption might be a result of two effects. By drawing additional attentional resources to the location of the change, this may impair subsequent inhibition of these items. Or, potentially the visual system might “magnify” the change, to ensure its interpretation as a new item. In both cases, this would serve to heighten the disruption to the Preview Benefit, demonstrated in Chapter 7. More importantly, both of these mechanisms would achieve the same result; the behavioural importance of a face would be afforded special status in the visual system.

Lastly on this point, the effects of comparative physical changes (i.e. between the stimuli used in Experiments 10 and 11, and those used in Watson & Humphreys, 2002) might also relate to another aspect of the face processing debate. If the holistic processing of facial stimuli (e.g., Farah et al., 1998) is not wholly accepted, particularly in the case of facial schematics, it may be that the impact of this change is enhanced by a feature-based processing mechanism. This would mean that the feature change to the mouth (i.e. that “drives” the expression change as a whole) should be considered to be of greater magnitude- on a par with the physical changes used in previous work (i.e.

Watson & Humphreys, 2002, 2005; Watson et al., 2008). However, this would be difficult to reconcile with the findings of Chapter 5 (i.e. that facial stimuli cannot be fully suppressed in the preview search paradigm), as search based on the mouth feature alone, would presumably have allowed a more complete preview benefit.

8.3.7 *The absence of valence-based differential processing in facial expression change*

The lack of differential valence-based processing was surprising in this case. Given the argument that negatively valenced faces attract some form of privileged processing, due to their behavioural importance, one would predict that the ability to detect an expression change from neutral to negative valence would be enhanced when compared with a change from neutral to positive valence. However, in this case, similarly to Chapter 5, where no differential processing was demonstrated between valenced previews, both valenced expression changes elicited similar disruption to the preview benefit. At first glance, this finding might be taken to reflect the general salience of emotional faces (see Palermo & Rhodes, 2007; for a review) or any emotional aspect of the individual's environment (i.e. Compton, 2003). Conversely, this could also be taken as sensitivity to generalized facial emotion (i.e. any emotional display is important, but all are of equal relevance; e.g., Martin et al., 1991).

It is possible that this finding emerges from a similar processing context to that in Chapter 5; as there is no temporal constraint on processing the changed facial expression, it could be that sufficient time is allowed for the observer to determine threat, or whatever further evaluation is required. Thus, by the time a response is made, it may be that valence-based differential processing has dissipated, and the negative and positive expressions are treated as equivalent. Alternatively, it may be that a change in facial expression has a high salience to the visual system per se, in accordance with its importance to the observer's subsequent behaviour, and that applies equally to negative and positively valenced facial expressions.

8.3.8 *Consistency with previous work examining faces in visual search: The negative target search advantage and time-based selection*

An interesting side issue in this thesis was to establish whether the typical advantage for negative stimuli would persist under time-based selection conditions. However, note that direct comparison with much of the previous work exploring visual search with emotionally valenced faces is not without issue. Most saliently, the primary focus of many of these studies has been the attention-capturing properties of valenced faces as targets, rather than the effects of a valenced distractor set (although this point has been discussed in some of that work, see Williams et al., 2005b; Eastwood et al., 2001; Fox et al., 2000; Hampton et al., 1989; Hansen & Hansen, 1988). Moreover, the preview search paradigm not only evaluates the attentional effects of part of that distractor set, but also relies on the reverse attentional function (i.e., ignoring stimuli rather than detecting them).

However, leaving aside these differences, it is clear that a search advantage for negative targets was demonstrated throughout each of the chapters above. In terms of search alone then, detection of a negative face amongst neutral or positive faces was more rapid than detection of a positive face amongst neutral or negative faces and taken as a whole, this thesis should be taken as support for the *negative superiority effect.* In addition, it is important to acknowledge that these findings extend the negative valence/threat superiority effect to conditions of temporal selection.

One particular point of interest arising from examination of simple target detection effects, was that, contrary to the findings of Williams et al. (2005, but cf. Williams et al., 2008), no reliable effect of whether or not participants knew (or could predict) the identity of the target valence was demonstrated in Chapter 5. This held equally for both negative and positive targets. This might have been because the effect of top-down knowledge was not sufficiently strong to override the effects of the negatively valenced stimuli. However, in practical terms, this finding allowed the use of schematic emotional face search to be extended beyond simple spatial selection and into the domain of temporal selection (i.e. the preview search paradigm). Recall that this paradigm required participants to have knowledge of the target's valence throughout each experiment, and that much of the previous work examining faces in visual search had relied on a methodology where participants searched for the "odd-one-out".

More importantly, however, it also indicated that the attentional biases elicited by emotionally valenced faces are not overridden by top-down awareness of target identity or emerging top-down task demands in the visual search context. It is not clear why different results were obtained to those found by Williams et al. (2005), since this methodology matched that study relatively closely. However, the face stimuli used in Williams' study were photographic, and may have introduced confounds on the basis of distinctive features (i.e., stimuli comprising a display of teeth) or target-distractor similarity (i.e., the features displayed in less-well detected stimuli may have resembled the emotionally neutral face distractors to a greater degree). Moreover, in a recent neuroimaging study, Williams et al. (2008) also found no effects of instruction set (i.e., knowledge of target identity) on target valence, in either behavioral or neuroimaging data. Clearly the exact conditions under which top-down knowledge can impact on the effects of stimulus valence remain to be determined.

8.3.9 *Implications for theories of time-based selection*

In terms of contribution to the theoretical background of temporal selection in visual attention (see Chapter 2, for more detail), these findings speak directly to the explanations given for the preview benefit. Although clearly, this thesis has emerged from the perspective of the inhibitory *visual marking* account (Watson & Humphreys, 1997), alternative explanations of the preview benefit have been proposed. Thus, it may be that these findings can help to inform the debate between these competing accounts.

The *abrupt onset* account (Donk & Theeuwes, 2001) argues that the preview benefit occurs because the abrupt luminance onsets of new items capture attention automatically, leading to the prioritized selection of those elements. Alternatively, the *temporal asynchrony* account (Jiang et al., 2002) proposes that elements within each set of stimuli (old and new) group independently, based on their common, but asynchronous onset. Attention can then be applied to either group, depending upon task demands. Both of these accounts have difficulty explaining the present set of findings; however, these can be addressed in turn, and in relation to separate aspects of this thesis.

Firstly, in relation to the absence of a complete preview benefit, even when preview duration was extended beyond the typical duration of 1s, neither of the alternative accounts appear able to explain this effect adequately. In other words, if the preview benefit is simply due to new abrupt luminance onsets (i.e. new items in the visual field capturing attention automatically), then there appears to be no reason why a full preview benefit should not have been demonstrated with schematic faces, equally strongly as seen previously with more abstract stimuli. In fact, the new onset account does not seem to allow for any specialized attentional properties of either old or new items in the visual field. In addition, if temporal differences alone were crucial (Jiang et al., 2002) for a full preview benefit, then this account cannot explain why we obtained only a partial preview benefit with face stimuli, when the temporal asynchrony (temporal difference between the presentation of the old and new) was identical to that used in previous studies in which a full preview benefit was obtained.

More strikingly, neither of these accounts of the preview benefit provides explanation for the valence-based performance differences demonstrated at short latencies (i.e. 250-750ms). For example, Jiang and colleagues' (2002) standpoint would predict that, provided that the temporal difference between the old and new groups remains the same, then the preview benefit should also remain the same. However, this was patently not the case at shorter preview durations, where there was a differential effect of preview duration, depending upon the valence of the previewed items. Similarly, a pure luminance onset account cannot give any explanation for the differential effect of negative and positive faces at short preview durations, as the onset of both sets of new items would be equivalent in terms of luminance (i.e. both would comprise neutrally-valenced distractors and valenced target, defined by an upwards or downwards curve).

In contrast, an inhibitory account of the preview benefit (Watson & Humphreys, 1997; 1998), in which old stimuli have to be intentionally suppressed, can readily explain both of these features of the data. Any mechanism that relies on a top-down, capacity-limited, active inhibition process would necessarily be influenced by the attentional properties of the stimuli that are required to be suppressed.

In summary, despite the paucity of counter-argument from theoretical standpoints other than Watson and Humphreys' account (1997; 1998), it seems clear that neither alternative account hold much explicatory power in this instance. However, it should be acknowledged that much of the previous work, under the auspices of each of these three theoretical perspectives, has used abstract stimuli, with little ecological or behavioural relevance. It may be that investigations of either luminance-defined abrupt onsets of new items or segmentation via temporal asynchrony can add to this debate, if they evaluate the parameters of their proposed mechanism when applied to stimuli such as the schematic faces used in this thesis.

8.4 Implications for future work

The review of implications for current theory above, addresses a number of issues that are raised by the findings contained in this thesis. However inevitably, any empirical investigation will raise as many questions as it, in turn, answers. And whilst this may be frustrating in terms of leaving issues apparently unresolved, it is useful in that it may serve to inform future work- and to highlight where such work is needed. This section will examine some of these issues in more detail, and suggest where constructive progress may be made in these areas.

8.4.1 *Effects of valenced targets versus valenced distractors*

It should be noted that, in this thesis, no differentiation has been made between the potentially differing effects of emotionally valenced distractor sets and emotionally valenced targets, although this has been a discussion point for previous work (see Frischen et al., 2008; for a review, and Section 3.5.1.2, above). Moreover, in some investigations of visual search with faces, this point has been addressed directly by use of a search asymmetry methodology (see Horstmann, 2007; for a comprehensive review, and Hortsmann et al., 2006; for discussion of efficient rejection of positively valenced distractors). This has been previously indicated to be a diagnostic for evaluation of efficient (preattentive/parallel) processing (e.g., Treisman & Souther, 1985; Treisman & Gormican, 1988); however, this type of design was not appropriate for these investigations. Thus, it is possible that the valenced targets in these search tasks may have tended to attract attention to themselves, and in turn, have attenuated the preview benefit. That said, it is very difficult to evaluate the likelihood of this occurrence, given the constraints of the current paradigm.

In this way, a valuable goal for future work will be to disentangle the possible differing effects of distractor versus target valence in time based selection. This could be achieved by using similar, but non-facial stimuli, for example, a scrambled face target (or simple geometric shape) amongst non-scrambled face distractors (and vice versa; see Hershler & Hochstein, 2005, for an example of visual search with scrambled photographic faces; Fox et al., 2001, for visual search with jumbled schematic faces). However, it is also important to note that even some simple geometric shapes (e.g., triangles) have been shown to be processed (and evaluated) as threatening stimuli (i.e. Larsen et al., 2007) and also that some component features of negative faces (e.g., Tipples et al., 2002; and see Chapter 3) are considered threatening in themselves.

8.4.2 *Establishing why negative faces are more difficult to suppress*

There have been aspects of these findings that have not been easy to explain in precise terms. For example, differentiating between potential accounts of the selective impairment of suppressing negative faces (or establishing their relative contributions to the findings) is not possible here. However, that is not to say that this is not an important question to ask, or an interesting path to pursue in further research. In fact, it is possible to say that this is the natural *next step* for investigating faces in preview search.

Thus, a focus for future work might be to examine search efficiency with preview displays, in which both face and abstract neutral symbolic stimuli (e.g., letters, geometric shapes) are presented. In this way, if negative faces simply possess a stronger or more salient representation, then their presence should not interfere with the rate of suppressing accompanying abstract stimuli. However, if the negative faces capture or consume attentional resources, then they should also reduce the ease with which the previewed neutral abstract stimuli can be suppressed (compared with, for example, when the abstract stimuli are paired with positive faces). In either event, differentiating between the explanations presented above should be made considerably easier.

8.4.3 *Evaluation of stimulus valence*

8.4.3.1 *Conceptualizing negative affect*

The affective content of the valenced faces in these experiments have been unequivocal; there would be no debate regarding the valence of the happy and sad expressions conveyed by the facial schematics used. However, as discussed above (Chapter 3), the literature regarding faces in visual search has not been homogenous, in terms of the negative affect displayed by targets or distractors. For example, some authors have focused on conceptualizing faces as “threat versus non-threat”; interpreting threatening expressions as only those that indicate a direct threat to the observer (i.e. anger or fear). Others have focused on aspects of social threat, by interpreting negative affect as social disapproval (e.g., Kolassa et al., 2007; Rappee & Heimberg, 1997), communication of affective ambiguity (e.g., Whalen et al., 1998) or, as seen in this work; a broad negative versus positive valence-based distinction. The reasons for adopting this approach have been discussed at length in Chapter 3 above, and have been borne out by the pervasive negative target search advantage demonstrated throughout this thesis

However, leaving aside any questions of individual facial features (i.e. eyebrows, Tipples et al., 2002), there remains a wealth of facial schematics that might be utilized to investigate the differences between distinct negative facial expressions. That said, once schematic faces deviate from the simplistic representations used in this thesis, they become more difficult to control and arguably, open to interpretation in terms of the expression conveyed. For this reason, it might be preferable to use photographic faces, which comprise sufficient detail for more subtle affective displays. These would also lend an additional ecological validity, which schematic faces lack, despite their apparent equivalence with photographic faces, in respect of processing (e.g., Wright et al., 2004; Sagiv & Bentin, 2001).

8.4.3.2 *Stimulus norming for affective valence*

A remaining issue for the stimuli used in this thesis is one of contextual construction. Whereas negatively and positively valenced faces have been easy to construe affectively, the neutral face has been harder to define. Evidence from the computer science literature exploring face processing suggests that a *face space* context is sufficient to influence observer's interpretation of facial expression (e.g., Neth & Martinez, 2009), and that displaying a face at the extreme of a valence continuum can affect categorization of subsequent faces along that continuum. Moreover, this has been recently demonstrated in a particularly striking way (Becker, 2009), using fearful faces- given that these are believed to activate evolutionarily old areas of the brain, dedicated to fear processing (e.g., LeDoux, 1996, 1998; Öhman, 2003; Öhman & Mineka, 2001).

In this way, it may that participants have accepted the affective neutrality of these schematic faces in this thesis, based solely on the context of the valenced face stimuli presented alongside them. Certainly, there is no evidence from the data that neutral faces have been interpreted otherwise, and previous studies (e.g., Eastwood et al., 2001; Öhman et al., 2001; Fox et al., 2000) have provided a degree of stimulus validation in this respect. However, it may be that if these neutral facial schematics are evaluated context-free, they will be interpreted somewhat differently. Anecdotally, a number of observers have spontaneously reported an element of negative valence appertaining to the neutral stimulus, over the course of this work. A large scale, but straightforward assessment of the relative positive and negative affective ratings of each of these schematics (in varying affective contexts, according to their accompanying faces), together with measures of associated arousal (i.e. the Self-Assessment Manikin Scale; Lang, 1980; see Kolassa et al., 2007, for an example of its use) would provide valuable insight into this issue.

8.4.4 *Facial schematics and the Preview Benefit*

Despite extending the preview duration to a length sufficient to allow suppression of other stimuli resistant to suppression (i.e. stimuli isoluminant with their background; see Braithwaite et al., 2006), a full preview benefit was not demonstrated at any point for schematic faces. Explanations that account for this finding have been discussed above, however, there is also potential for exploring this issue experimentally. Given that facial schematics are have been open to criticism of part-based processing (rather than the holistic processing, characteristic of faces; e.g., Farah et al., 1998); decomposing the stimulus into its component parts and then, systematically evaluating preview search efficiency as the stimulus is gradually “re-assembled” would give such opportunity.

For example, if simple arcs (curving upwards and downwards; similar to the mouths of negative and positive faces in this thesis) were presented in the same experimental format as we have previously presented schematic faces, one could predict that observers would be able to inhibit these stimuli fully, showing a complete preview benefit. Thus, as components of the schematic face are added in (i.e. the circular “facial” outline; “eyes” and “mouths”, individually *and* in combination), these data would speak to i) the nature of schematic facial processing (i.e. at what point is the stimulus processed as a face? When might we suggest that holistic processing is taking place?) and, ii) the interaction of “faceness”, affective valence and temporal selection.

Evidence from the general face processing literature will be influential in how one would formulate predictions in this instance. For example, some work has suggested that the facial outline is critical to interpreting a stimulus as *face-like* or placing individual features into a facial context (e.g., Freiwald, Tsao, & Livingstone, 2009; Schübo et al., 2007), whereas other authors have focused on the eyes or mouths as features that attract preferential processing (e.g., Fox & Damjanovic, 2006; Whalen et al., 2004). In fact, Eastwood et al., (2003) utilized the simplistic arc shapes, used in this thesis to represent mouths, to construct valenced face-like stimuli that successfully influenced performance in an enumeration task. Overall, this suggests a course of investigation that, despite its experimental simplicity, could be potentially far-reaching in its impact.

8.4.5 *Possible influence of participant anxiety levels*

Several studies have identified the importance of self-reported anxiety (SRA) where valenced faces are used in visual attention paradigms (e.g., visual search, probe detection and cueing studies). Typically, differential effects of negatively valenced faces are demonstrated by high anxiety participants compared with low anxiety participants (e.g., Fox et al., 2001; Mogg & Bradley, 1999; see also Bishop et al., 2004, for converging neurophysiological evidence). That said, some authors have gone so far as to differentiate between separate facets of anxiety by focusing on, for example, social anxiety (e.g., Kolassa et al., 2007).

In the experiments reported in this thesis, SRA was not measured; for the most part, because individual differences and personality traits were not central to the main research questions. Moreover, because participants were randomly allocated to experiments/conditions, it is possible to assume that anxiety levels (or similar individual differences) would not have varied systematically across any of these experiments. Nonetheless, a potentially important goal for future work will be to assess the possible influence of anxiety on time-based visual selection with valenced stimuli, especially given its established influence in attentional processing.

Specifically, it might be more difficult for high SRA individuals to ignore negative valence faces, or it might take longer for them to ignore them. For this reason alone, it would be useful to measure SRA levels in future work, as a confirmatory check that anxiety levels do not differ across conditions or experiments. In addition, as other authors have evaluated observer state/trait effects via specific subcategories of anxiety (i.e. social anxiety; with faces that could be interpreted as “socially disapproving”), or mood disorders (e.g., Suslow et al., 2001, 2003), it might be useful to extend this type of work to more clinically or forensically specialized samples, where previous evidence might suggest an aspect of differential affective face processing (i.e. sex offender populations; see for example, Oliver, Watson, Gannon & Beech, 2009).

8.4.6 *Using colour to support inhibitory processes in preview search*

The findings outlined in Chapter 7 (and subsequently, discussed above), demonstrated a clear disruption to the preview benefit when a change in facial expression was made to preview neutral faces. That said, whilst no reliable effects attributable to valence- based performance differences were demonstrated, several trends in the data suggested avenues for further investigation. Thus, it appears important to examine the parameters of expression change to previewed faces more closely; specifically, to explore in more detail where valence-based differences, if any, might lie.

Previous work examining the effect of changes to previewed items (Watson et al., 2008), has demonstrated that, in some situations, disruption of preview benefit may be reduced or abolished by addition of a feature, other than those defining the target (in this instance, colour), to the preview stimuli. The rationale behind this manipulation suggests that, where a feature of the to-be-ignored items enables these items to be successfully grouped and suppressed together (via inhibition of the feature in question, and adoption of an anticipatory set for the colour of new items; Watson et al., 2008), this allows improved performance in the preview condition.

Thus, future investigations might include previewed facial stimuli (changing from neutral to negatively and positively valenced expressions, similarly to Experiments 10 and 11) appearing in a different colour to the remainder of the distractor set and target. Although use of particular colours would not be not prescriptive, those used in the study by Watson and colleagues (i.e. blue; RGB= 68,164,176, and green; RGB= 11,193,126; Watson et al., 2008) have already been well-validated. This is both in the sense of their use within the preview search paradigm, and the matching of their perceptual properties.

In this way, it might be possible to mitigate disruption of the preview benefit, in a similar manner to how Watson & Humphreys (2008) effectively "bolstered" their stimuli's resistance to large local luminance changes. Moreover, if this proved possible in the case of valenced schematic faces, it might also be feasible to examine any valence-based differences in subsequent preview search performance, even if these were small in magnitude. In reality, however this measure operates in relation to expression changes made to previewed faces, certainly it would serve to elucidate the current equivocation in findings.

8.5 Concluding remarks

This thesis has shown that it is possible to ignore face stimuli over time, in order to prioritize newly appearing information. However, it seems apparent that this ability is limited, possibly by adaptive mechanisms preventing complete disengagement from behaviourally relevant stimuli (i.e. demonstration of a full preview benefit; Watson & Humphreys; 1997; 1998). Moreover, these findings have raised important questions relating to the parameters of attentional resource allocation in the case of valenced faces, and the impact of attentional resource and adaptive processing mechanisms upon human cognitive flexibility. In turn, these findings have been able to contribute to the debate surrounding the source of the search advantage that emanates from previewing a subset of distractors, prior to searching through a full search array (i.e. the *preview benefit;* Watson & Humphreys, 1997, 1998)

In addition, this thesis has shown that the affective valence of these faces is important, but only insofar as differentiation is made between negative and positive valenced faces by the visual system, i) at short latencies (i.e. 250-750ms), and ii) where valenced faces are used as targets. Extending the demonstration of the negative valence/ threat search advantage to temporal selection in visual attention is also particularly important. In circumstances when equal importance can be applied to negatively and positively valenced faces, or, when sufficient time has elapsed for adequate evaluation of valenced stimuli, the visual system appears to attribute equivalent salience to both affective valences. This includes processing when active, top-down inhibition of valenced faces is required (i.e. *visual marking*; Watson & Humphreys, 1997; 1998), specifically, with preview durations longer than 1s, and where ecologically-relevant changes are made to the facial expressions of previewed faces. However, further investigation of the latter experimental context would appear particularly useful.

Questions that have arisen from the findings outlined above suggest particularly interesting routes for future work. Not only have these findings provided a sound empirical basis from which to move forward, but they have also indicated the value of further investigation. Moreover, this view can be supported from the perspective of both the face processing and visual attention literatures.

In terms of the facial stimuli used, this thesis provides robust evidence that emotionally–valenced schematic faces are suitable stimuli for examination of attentional phenomena requiring a high level of experimental control. And yet, that is not to say that future exploration of these (and similar) phenomena should not strive to extend understanding beyond the laboratory. This might include more realistic representations of human faces (i.e. photographic faces) or even measures that allow ecologically-valid investigation extending into the real world (see, for example, the recently proposed principles of *Cognitive Ethology*; Kingstone, Smilek, & Eastwood, 2008).

Arguably then, this is where any enduring relevance of the work contained in thesis lies. Indubitably, examination of mechanisms underlying human visual and attentional processing requires precision and rigorous scientific control. It may be that this can only be achieved via use of abstract stimuli within experimental contexts. However if, as scientists, we strive to overlay meaning onto our experimental findings, it is necessary to formulate questions that have direct relevance to human experience. In extending understanding of faces, their attentional properties, and the effects of emotional valence, it is possible to say that this thesis rises to that challenge.

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